Henry H. [illegible]

THE

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OF

USEFUL KNOWLEDGE.

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The Boston Society for the Diffusion of Useful Know

VOL. I.

CONTAINING

Judge Story's, Mr. Webster's, and Mr. Everett's
before the Mechanics' Institution; Mr. Everett's *Lectur*
Working Men's Party; Lord Chancellor Brougham's *Diss*
on the Objects, Advantages and Pleasures of Science, and his
of Lord Bacon's *Novum Organon,* Part I.; and the First Pa
Herschel's *Discourse on the Study of Natural Philosoph*

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PREFACE.

The design of this publication is to furnish a collection of such works, on the most important branches of knowledge, as ought to be in the possession of every intelligent family. It is intended to embrace in it only works of permanent utility, and such as will present the subjects of which they treat in the most authentic form, with the advantage of all the lights which shall have been shed upon them, by the labors of the learned and scientific, up to the time of publication. It will consist, in part, of approved works of foreign origin, which shall be considered particularly adapted to the object in view, and, in part, of works written for the purpose, by distinguished native authors, under the direction of the editor, and the sanction of the Society which has interested itself in the promotion of the publication. The series will consist of independent works, some of them extending to the compass of three or four volumes, but such as, when taken together, will form a well assorted library. It is intended that each work shall be written in a style which shall be intelligible to the careful reader, although he may have little other previous acquaintance with the particular subject treated of, than may have been acquired from the preceding volumes of the series; yet it is hoped that they will be regarded as far from superficial, and that they will not be thought unworthy of the attention of the accomplished scholar and man of science. Controverted doctrines will be, as much as possible, avoided, and the great aim of the work will be to aid in the general dissemination of facts and principles, which most enlightened men unite in regarding as true, and worthy of being generally known.

Boston, June 10, 1831.

CONTENTS.

A DISCOURSE

DELIVERED

BEFORE THE BOSTON MECHANICS' INSTITUTION, AT THE OPENING OF THEIR ANNUAL COURSE OF LECTURES, NOVEMBER, 1829.

BY JOSEPH STORY.

Gentlemen,

Much has been said respecting the spirit of our age, and the improvements, by which it is characterized. Many learned discussions have been presented to the public with a view to illustrate this topic; to open the nature and extent of our attainments; to contrast them with those of former times; and thus to vindicate, nay more, to demonstrate, our superiority over all our predecessors, if not in genius, at least in the perfection and variety of its fruits. There is doubtless much in such a review to gratify our pride, national, professional and personal. But its value in this respect, if we stop here, is but of doubtful, or at least of subordinate importance. It is not the sum of our attainments, but the actual augmentation of human happiness and human virtue thereby, of which we may justly be proud. If every new acquisition operates as a moving spirit upon the still depths of our minds, to awaken new enterprise and activity, to warm our hearts to new affection and kindness to our race, and to enable us to add something to the capital stock of human enjoyment, we may well indulge in self-congratulation. It has been said, that he, who makes two blades of grass grow, where one

only grew before, deserves to be reckoned among the benefactors of mankind. And it has been justly said; because he has added so much means to the support of life, and thus promoted the effective power and prosperity of the whole community. The true test of the value of all attainments is their real utility.

I do not mean by this remark to suggest, that nothing is to be esteemed valuable, except its utility can be traced directly home to some immediate benefit, in visible operation as an effect from a cause. Far otherwise. There are many employments, whose chief object seems little connected with any great ultimate benefit, which yet administer widely, though indirectly, to the substantial good of society. There are many studies, which seem remote from any direct utility, which yet, like the thousand hidden springs, which form the sources and streams of rivers, pour in their contributions to augment the constantly increasing current of public wealth and happiness. We must, not, therefore, when we examine an art, or an invention, a book, or a building, a study or a curiosity, measure its value by a narrow rule. We must not ask ourselves, whether we could do without it; whether it be indispensable to our wants, or, though missed, could yet be spared. But the true question in such cases ought to be, whether in the actual structure of society, it gratifies a reasonable desire, imparts an innocent pleasure, strengthens a moral feeling, elevates a single virtue, or chastens or refines the varied intercourse of life. If it does, it is still useful in the truest sense of the term, although it may not seem directly to feed the hungry, cure the sick, administer

consolation to the afflicted, or even remove the irksome doubt of a poor litigant groping blindfold through the dark passages of the law.

It is not easy, indeed, to name many pursuits, of which the inutility is so clearly made out, that they may be parted with without regret, or without disturbing the good order and arrangements of society. Some that at a short sight seem, if not frivolous, at least unnecessary, to men of narrow capacities, will be found on a larger survey, to be connected with the most important interests. The fine arts, for instance, painting, music, poetry, sculpture, architecture, seem almost the necessary accompaniments of a state of high civilization. They are not only the grace and ornament of society, but they are intimately connected with its solid comforts. If they did no more than gratify our taste, increase our circle of innocent enjoyment, warm our imaginations, or refine our feelings, they might be fairly deemed public blessings. But who is so careless, as not to perceive, that they not only give encouragement to men of genius, but employment to whole classes in the subordinate arts? They not only create a demand for labour; but make that very labour a means of subsistence to many, who must otherwise be idle and indolent, or by pressing upon other business, sink the compensation for labour, by a ruinous competition, to its minimum price. How many thousands are employed upon a single block of marble, before, under the forming hand of the artist, it breathes in sculptured life? Before it meets us in the surpassing beauty of a Venus, or the startling indignation of an Apollo? Our granite would have slum-

bered forever in its quarries, if architecture had not, under the guidance of taste, taught us to rear the dome, and the temple, the church of religion, and the hall of legislation, the column of triumph, and the obelisk of sorrow. To what an amazing extent are the daily operations of the press! With how many arts, with how much commerce, with what various manufactures, is it combined! The paper may be made of the linen of Italy and the cotton of Carolina, or Egypt, or the Indies; the type and ink of the products of various climes; and the text must be composed, and the sheets worked off, by the care and diligence of many minds. And yet if no books were to be printed, if no newspaper or pamphlet were to be struck off, but what were indispensable; if we were to deem all classical learning useless; and all poetry and fiction, and dissertation and essay, and history, a sad abuse of time and labour and ingenuity, because we could do without them; and because they did not plant our fields, or turn our mills, or sail our ships; I fear, that the race of authors would soon become extinct; and the press, busy, as it now is, with its myriads, would sink back into the silence of the days of Faustus, and require no aid from the supernatural arts of his suspected coadjutor. Sure I am, that the power-press of your own Treadwell, that beautiful specimen of skill and ingenuity, would be powerless, and no longer in its magical works delight us in our morning search, or in our evening lucubrations.

I have made these suggestions, not so much as appropriate to the objects, which I have in view in this address, as to guard against the supposition in what follows, that the

liberal arts are not worthy of our most intense admiration and respect.

If I were called upon to state, that, which upon the whole was the most striking characteristic of our age, that which in the largest extent exemplified its spirit, I should unhesitatingly answer, that it was the superior attachment to practical science over merely speculative science. Into whatever department of knowledge we search, we shall find, that the almost uniform tendency of the last fifty years has been to deal less and less with theory, and to confine the attention more and more to practical results. There was a period, when metaphysical inquiries constituted the principal delight of scholars and philosophers; and endless were the controversies and the subtleties, about which they distracted themselves and their followers. The works of Aristotle, one of the greatest geniuses of all antiquity, were studied with a diligence, which will hardly be believed in our day, and exerted an influence over the minds of men, almost down to the close of the seventeenth century, as wonderful, as it was universal. He was read, not in what would now be deemed most important, in his researches into natural history, and the phenomena of the external world, or in his dissertations on politics and government, and literature; but in his metaphysics, and endless inquiries into mind and spirit, and essences, and forms, and categories, and syllogisms.

Lord Bacon, two centuries ago, in some most profound discourses, exposed the absurdity of the existing system of study, and of its unsatisfactory aims and results. He vindicated the necessity of inquiring into mental as well as

natural phenomena by other means; by what is called the method of induction, that is, by a minute examination of facts, or what may properly be called experimental philosophy. This in his judgment was the only safe and sure road to the attainment of science, and by subjecting every theory to the severe test of facts, would save a useless consumption of time and thought upon vague and visionary projects.

It may seem strange, that such wise counsels should not be listened to with immediate if not universal approbation. The progress, however, even of the most salutary truths is slow, when there are no artificial obstacles in the way. But when men's minds are pre-occupied by systems and pursuits, which have received the sanction of many generations, every effort to overcome errors, is like the effort to carry an enemy's fortress. It can rarely be accomplished by storm. It must be subdued by patient mining, by a gradual destruction of outposts, and by advances under cover of powerful batteries. Lord Bacon's admonitions can scarcely be said to have gained any general credence until the close of the seventeenth century; and their triumphant adoption was reserved as the peculiar glory of our day.

It is to this cause, that we are mainly to attribute the comparatively slight attention at first paid to discoveries, which have since become some of the most productive sources, not only of individual opulence, but, in a large sense, of national wealth. The history of the steam-engine is full of instruction upon this subject. The Marquis of Worcester early in the reign of Charles II., (1655) first

directed the attention of the public to the expansive power of steam when used in a close vessel; and of its capacity to be employed as a moving power in machinery. The suggestion slept almost without notice, until about the year 1698, when Capt. Savery, a man of singular ingenuity, constructed an apparatus, for which he obtained a patent, to apply it to practical purposes. The invention of a safety-valve soon afterwards followed; and that again was succeeded by the use of a close fitted piston working in a cylinder. Still, however, the engine was comparatively of little use, until Mr. Watt, a half century afterwards, effected the grand improvement of condensing the steam in a separate vessel, communicating by a pipe with the cylinder; and Mr. Washbrough, in 1778, by the application of it to produce a rotatory motion, opened the most extensive use of it for mechanical purposes.

It was in reference to the astonishing impulse thus given to mechanical pursuits, that Dr. Darwin, more than forty years ago, broke out in strains equally remarkable for their poetical enthusiasm, and prophetic truth, and predicted the future triumph of the steam-engine.

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge, or drive the rapid car;
> Or on wide waving wings expanded bear
> The flying chariot through the fields of air;—
> Fair crews triumphant, leaning from above,
> Shall wave their fluttering kerchiefs as they move,
> Or warrior bands alarm the gaping crowd,
> And armies shrink beneath the shadowy cloud."

What would he have said, if he had but lived to witness the immortal invention of Fulton, which seems almost to

move in the air, and to fly on the wings of the wind? And yet how slowly did this enterprise obtain the public favour. I myself have heard the illustrious inventor relate, in an animated and affecting manner, the history of his labours and discouragements. When, said he, I was building my first steam-boat at New York, the project was viewed by the public either with indifference, or with contempt, as a visionary scheme. My friends, indeed, were civil, but they were shy. They listened with patience to my explanations, but with a settled cast of incredulity on their countenances. I felt the full force of the lamentation of the poet,

> "Truths would you teach, to save a sinking land,
> All shun, none aid you, and few understand."

As I had occasion to pass daily to and from the building-yard, while my boat was in progress, I have often loitered unknown near the idle groups of strangers, gathering in little circles, and heard various inquiries as to the object of this new vehicle. The language was uniformly that of scorn, or sneer, or ridicule. The loud laugh often rose at my expense; the dry jest; the wise calculation of losses and expenditures; the dull but endless repetition of the Fulton Folly. Never did a single encouraging remark, a bright hope, or a warm wish, cross my path. Silence itself was but politeness, veiling its doubts, or hiding its reproaches. At length the day arrived when the experiment was to be put into operation. To me it was a most trying and interesting occasion. I invited many friends to go on board to witness the first successful trip. Many of them did me the favour to attend, as a matter of per-

sonal respect; but it was manifest, that they did it with reluctance, fearing to be the partners of my mortification, and not of my triumph. I was well aware, that in my case there were many reasons to doubt of my own success. The machinery was new and ill made; many parts of it were constructed by mechanics unaccustomed to such work; and unexpected difficulties might reasonably be presumed to present themselves from other causes. The moment arrived, in which the word was to be given for the vessel to move. My friends were in groups on the deck. There was anxiety mixed with fear among them. They were silent, and sad, and weary. I read in their looks nothing but disaster, and almost repented of my efforts. The signal was given, and the boat moved on a short distance, and then stopped, and became immovable. To the silence of the preceding moment now succeeded murmurs of discontent, and agitations, and whispers and shrugs. I could hear distinctly repeated, "I told you it would be so—it is a foolish scheme—I wish we were well out of it." I elevated myself upon a platform, and addressed the assembly. I stated, that I knew not what was the matter; but if they would be quiet, and indulge me for a half hour, I would either go on, or abandon the voyage for that time. This short respite was conceded without objection. I went below, examined the machinery, and discovered that the cause was a slight mal-adjustment of some of the work. In a short period it was obviated. The boat was again put in motion. She continued to move on. All were still incredulous. None seemed willing to trust the evidence of their own senses. We left

the fair city of New York; we passed through the romantic and ever-varying scenery of the highlands; we descried the clustering houses of Albany; we reached its shores; and then, even then, when all seemed achieved, I was the victim of disappointment. Imagination superseded the influence of fact. It was then doubted, if it could be done again; or if done, it was doubted if it could be made of any great value.

Such was the history of the first experiment, as it fell, not in the very language which I have used, but in its substance, from the lips of the inventor. He did not live indeed to enjoy the full glory of his invention. It is mournful to say, that attempts were made to rob him in the first place of the merits of his invention, and next of its fruits. He fell a victim to his efforts to sustain his title to both. When already his invention had covered the waters of the Hudson, he seemed little satisfied with the results, and looked forward to far more extensive operations. My ultimate triumph, he used to say, my ultimate triumph will be on the Mississippi. I know, indeed, that even now it is deemed impossible by many, that the difficulties of its navigation can be overcome. But I am confident of success. I may not live to see it; but the Mississippi will yet be covered by steam-boats; and thus an entire change be wrought in the course of the internal navigation and commerce of our country.

And it has been wrought. And the steam-boat, looking to its effects upon commerce and navigation, to the combined influences of facilities of travelling and facilities of trade, of rapid circulation of news, and still more rapid

circulation of pleasures and products,, seems destined to be numbered among the noblest benefactions to the human race.

I have passed aside from my principal purpose to give in this history of the steam-boat, a slight illustration of the slow progress of inventions. It may not be unacceptable, as a tribute to the memory of a man, who united in himself a great love of science with an inextinguishable desire to render it subservient to the practical business of life.

But perhaps the science of chemistry affords as striking an instance as any, which can be adduced, of the value of Lord Bacon's maxims, and of the paramount importance of facts over mere speculative philosophy. It was formerly an occult science, full of mysteries, and unedifying processes, abounding in theories, and scarcely reducible to any rational principles. It is now in the highest sense entitled to the appellation of a science. The laws of chemical action have been examined and ascertained with great accuracy, and can now be demonstrated with as much clearness and facility, as any of the laws, which belong to mechanical philosophy. It has become eminently a practical science; and its beneficial effects are felt in almost every department of life. The apothecary's shop no longer abounds with villanous compounds and nostrums, the disgrace of the art. Chemistry has largely administered to the convenience as well as the efficacy of medicines, by ascertaining their qualities, and component parts, by removing nauseous substances, simplifying processes, and purifying the raw materials. It has secured

the lives of thousands by its wonderful safety lamps, which prevent explosions from the invisible but fatal fire-damps of mines. It lights our streets and theatres by its beautiful gas, extracted from coal. It enters our dye-houses, and teaches us, how to fix and discharge colors, to combine and to separate them; to bleach the brown fibre, and impart the never-fading tint. It discloses the nature and properties of light and heat, of air and water, of the products of the vegetable and animal kingdoms, of earths and alkalies, and acids, and minerals, and metals. And, though we have not as yet discovered by it the philosopher's stone, or learned how to transmute all other substances into gold, we have gained by it a much more valuable secret, the art of improving our agriculture, perfecting our manufactures, and multiplying all our comforts, by giving new power to all the arts of life, and adding new vigour to a home-bred industry. It has indeed conferred benefits, where they have been least expected. By expounding the origin and causes of ignes fatui, it has put to flight the whole host of goblins, and imps and fairies, and sprites, that inhabited our low grounds and wastes, and required some holy incantation to lay them in the good old days of superstition and omens, and death watches and ghosts, that vanished at the crowing of the cock. It may not, indeed, be said to have given much aid to the law, except when some luckless inventor has been driven into a tedious lawsuit by an infringement of his patent, and has found his money melt away under its dissolving power.

Half a century ago the composition of the atmosphere and ocean were unknown to philosophy. The identity of

the electric fluid and lightning was scarcely established. The wonders disclosed by the galvanic battery had not even entered into the imagination of man.

It is unnecessary for me to trace the causes, which gradually led to these changes in the objects and pursuit of science. For a long period after the revival of letters, the minds of educated men were almost wholly engrossed by classical learning, and philology, and criticism, and dogmatical theology, and endless commentaries upon scanty texts both in law and divinity. The study of pure and mixed mathematics succeeded; and astronomy, as it deserved, absorbed all the attention and genius, which were not devoted to literature. But scholars of all sorts, by general consent, looked with indifference or disdain upon the common arts of life, and felt it to be a reproach to mingle in the business of the artizan. One should suppose, that the alliance between science and the arts was so natural and immediate, that little influence would be necessary to bring about their union. But the laboratory and the work-shop, the study of the geometrician, and the shed of the machinist, were for ages at almost immeasurable distances from each other; and the pathways between them were few and little frequented.

It was not until some fortunate discoveries in the arts had led to opulence, that scientific men began to surrender their pride, and to devote themselves practically to the improvement of the arts. The first great step in modern science was to enter the work-shop, and superintend its operations, and analyze and explain its principles. And the benefits derived from this connexion have already

been incalculable both to art and science. Each has been astonishingly improved by the other; and a hint derived from one has often led on to a train of inventions and discoveries, the future results of which are beyond all human power to measure. Thus, dignity and importance have been added to both. The manufacturer, the machinist, the chemist, the engineer, who is eminent in his art, may now place himself by the side of the scholar, and the mathematician, and the philosopher, and find no churlish claim for precedency put in. His rank in society, with reference either to the value of the products of his skill, or the depth of his genius, sinks him not behind the foremost of those, who strive for the first literary distinctions. This fortunate change in the public opinion, which has made it not only profitable, but honourable to pursue the mechanical arts, is already working deeply into all the elements of modern society. It has already accomplished, what it is scarcely a figure of speech to call, miracles in the arts. Who is there, that would not desire to rival, if he does not envy, the inventions of Watt, of Arkwright, and Fulton? Who would ask for a fairer reputation, or loftier or more enduring fame, than belongs to them? And yet we have but just entered on the threshold of the results, to which their labours must lead future generations. We can scarcely imagine the number of minds, which have been already stimulated to the pursuit of practical science by their successful example. Whichever way we turn, we may see minds of the first class diverted from the established professions of law, physic, and divinity, to become the votaries, nay the enthusiastic votaries, of the arts. And

we are beginning to realize the first effects of this intense application and appropriation of the genius of our age in simultaneous, and elegant inventions.

It is true in the general progress of society, that art generally precedes science. The savage first constructs his hut, prepares his food, fashions his weapons of defence, and multiplies his power, by the application of the rudest materials. His wants being supplied, he may then dream of luxuries. But the road lies open to him, not by the investigation of principles, but by the application of manual dexterity, and steady labour to acquire them. And this for the most part continues, or rather has continued to be the order of things, until very late stages of civilization and refinement. At present this order is almost entirely reversed. It may now be said with truth, that in a general view science precedes art; that is, the improvements, which are made in art, arise more often from an exact investigation of principles, than from bare experiments or accidental combinations. Principles suggest the experiment, rather than experiment the principles. In the most important branches of manufactures, where skill is so constantly in demand, and economy in operation is so indispensable, and competition is universal, there is now a perpetual tasking of the wit of man to invent some cheaper, thriftier, or neater combination. Something to increase the velocity, and uniformity of motion, the delicacy and certainty of spinning, the beauty or fineness of fabrics, the simplicity or directness in application of power, or something to ascertain and separate the worthless from the valuable in materials, is the ambition of a thousand minds

at the same instant; and the project holds out ample rewards to the fortunate discoverer. The result is, that the discovery is often simultaneously made by different minds at great distances, and without the slightest communication with each other. At other times different inventions are at the same moment employed, and work out with rival skill the same purposes by opposite means. In this way, and especially in manufactures, the most perfect existing machinery is perpetually in danger of becoming useless, or at least unprofitable, by the introduction of a single improvement, which gives it a superiority of one per centum upon the capital employed. An instance, illustrative of these remarks, occurred in the course of my own official duties, in a suit for the infringement of a patent right. A beautiful improvement had been made in the double-speeder of the cotton spinning machine, by one of our ingenious countrymen. The originality of the invention was established by the most satisfactory evidence. The defendant, however, called an Englishman as a witness, who had been but a short time in the country, and who testified most explicitly to the existence of a like invention in the improved machinery in England. Against such positive proof there was much difficulty in proceeding. The testimony, though doubted, could not be discredited; and the trial was postponed to another term, for the purpose of procuring evidence to rebut it. An agent was despatched to England, for this and other objects; and, upon his return, the plaintiff was content to become nonsuited. There was no doubt, that the invention here was without any suspicion of its existence elsewhere; but

the genius of each country, almost at the same moment, accomplished independently the same achievement.

I have introduced these considerations to the view of those, who are engaged in the arts, and especially of those, whose studies this Society is designed to patronize, for the purpose of leading them to the reflection, that in the present state of things it is no longer safe to be ignorant, and that mere dexterity and mechanical adroitness, expertness of hand, or steadiness of labour, are not alone sufficient to guaranty to the individual a successful issue in his business. Science is becoming almost indispensable, in order to master improvements, as they occur, and to keep up, in some measure, with the skill of the age. It will otherwise happen, that a mechanic, by the time he has arrived midway in life, will find himself superseded by those, who, though much younger, have begun life under more favorable auspices. But upon this I may have occasion to enlarge a little more hereafter.

I have already spoken of the advantages resulting from scientific men becoming familiar with the work-shop, and the operations of art. But a far more important object, and the second great step in improvement, is to elevate mechanics and artizans to the rank of scientific inquirers.

It is singular, that no attempt was ever made to provide systematically for such an object, until a period so recent, that it seems but an affair of yesterday. The truth is so obvious, that he, who is engaged in the practice of an art, must, with equal advantages, be far better qualified to improve and perfect its operations, than he, who merely theo-

rizes without any knowledge of practical difficulties, that it is matter of surprise, that it should have been so long overlooked. The origin and history of Mechanics' Institutions was brought before you on the first opening of your own Institution, with so much fulness and accuracy, by the learned gentleman, who addressed you on that occasion, that I may well be spared any effort to retouch, what he has so faithfully delineated. Until the nineteenth century no one thought of a system of scientific instruction, much less of mutual instruction, for those, who were to be bred in the arts. These institutions began, as you know, under the auspices of Professor Anderson, at Glasgow, and so slowly worked their way into public favour, that ten years ago they were unknown in that city, which boasts herself the modern Athens, and seven years ago all the influence and reputation of Dr. Birkbeck were requisite to introduce them into the reluctant circles of London.

I look upon this as a new era in the history of science; and it may be safely predicted, that these establishments are destined hereafter to work more important changes in the structure of society, and in the improvement of the arts, than any single event, which has occurred since the invention of printing.

What I propose in the residue of this discourse is, to offer some considerations in vindication of this opinion, and also some considerations by way of encouragement to those, who, as mechanics and artizans, are incited to devote themselves to the pursuit of liberal science.

And in the first place I might remark, that genius and talent are limited to no rank or condition of life. They

have been distributed by the bounty of Providence, with an equal hand, through every class of society. They are among those gifts, which poverty cannot destroy, or wealth confer; which spring up in the midst of discouragements and difficulties, and like the power of steam, acquire new elasticity by pressure; which ripen in the silence of solitude, as well as in the crowded walks of society; which the cottage may nourish into a more healthy strength, than even the palace, or the throne. The most formidable enemy to genius is not labor, but indolence; want of interest, and excitement; want of motive to warm, and of object to accomplish; ignorance of means, leading to indifference to ends. Hence it is, that the very highest and the very lowest orders of society, often present the same mental phenomena—a fixed and languishing disease of the intellectual powers, where curiosity wastes itself in trifles, and a cold listlessness, brooding over the thoughts, lets fall a preternatural stupor. Their misfortune is that, so beautifully touched by the poet

> "But knowledge to their eyes her ample page,
> Rich with the spoils of time, did ne'er unroll."

I might remark in the next place, that the rewards of science are most ample, whether they be viewed in reference to personal enjoyment, to rank in society, or to substantial wealth.

It is one of the wise dispensations of Providence, that knowledge should not only confer power, but should also confer happiness. Every new attainment is a new source of pleasure; and thus the desire for it increases as fast as it is gratified. It not only widens the sphere of our

thoughts, but it elevates them, and thus gives them a livelier moral action. When one has seen an apple fall from a tree, and is told for the first time, that its fall is regulated by the law of gravitation, the simplicity of the truth may scarcely awaken his curiosity. When he is told, that the same law regulates the plumb line, and enables him unerringly to erect his house in the true perpendicular, he perceives, with pleasure, a new application of it. When he is further told, that there is a constantly increasing rapidity in every descending body by the same law, so that it falls in the second instant double the space it does in the first; and that the whole doctrine of projectiles, both in nature and art, depends upon it; that it governs the flow of rivers, and the fall of cataracts, and the gentle rains, and the gentler dews, and the invisible air; that it guides the motion of the water-mill, the aim of gunnery, and the operations of the steam-engine; he cannot but awaken to some emotions of admiration. But, when he has been taught, that the same law regulates the ebb and flow of the tide, the motions of the earth and the planets, and the sun, and the stars, and holds them in their orbits, and binds them in an eternally revolving harmony; that to this he owes the return of day and night, the changes of the seasons, seed-time and harvest, summer and winter; if he be any thing but a clod of the valley, how can he but exclaim, in wonder and amazement,

> "These as they change, Almighty Father, these
> Are but the varied God. The rolling year
> Is full of thee."

What can tend more to exalt the dignity of our nature;

than the consideration, that the mind of man has not only been able to grasp and demonstrate this law, but to apply it to the solution of an infinite number of questions, apparently beyond the reach of his boldest efforts. He has been able to ascertain the motions and size of the whole planetary system; to calculate every perturbation arising from the constant but changeful influence of mutual gravitation; to ascertain the paths of comets; to calculate eclipses with unerring certainty, and to foretell the very minute, nay, the very instant, of occultation of the most distant satellites. He can thus read through the past, as well as the future, all the various states of the heavens for thousands of years. He has been able to apply this knowledge to the noblest purposes; and the mariner, by its aid, descries his home-port with the same ease on the dark bosom of the ocean, as he points it out from the little hill-top, that overlooks his native village.

If we pass from the contemplation of this sublime law of nature to others, which belong to animal or vegetable life, to those, which form and preserve the treasures of the earth, and of the sea, even down to those, which regulate the minutest particles of matter, the light of science will enable us every where to behold new and increasing wonders, and to remark the operations of infinite power, forever varied, and yet forever the same. It is impossible, that the mere perception of such laws should not afford pleasure to every rational mind. But when we further learn, that these very laws are made continually subservient to the use of man; that by the knowledge of them he is enabled to create power, and perfect mechanical

operations; that he can make the winds and the waves, the earth and the air, heat and cold, the ductile metals, and the solid rocks, the fragile flower, and the towering forest, minister to his wants, his refinements, and his enterprise, we are compelled to admit, that the capacity to trace back such effects to their causes, must elevate, and enlarge, and invigorate the understanding.

There is also real dignity, as well as delight, in such studies; and whenever they shall become the general accompaniment of mechanical employments, they must work a most beneficial change in the general structure of society. The arts of life are now so various and important, so intimately connected with national prosperity, and individual comfort, that for the future, a very large proportion of the population of every civilized country must be engaged in them. The time is not far distant, when the mechanic and manufacturing interest will form the great balancing power between the conflicting interests of commerce and agriculture, between the learned professions, and the mere proprietors of capital, between the day labourer, and the unoccupied men of ease. In proportion to the degree of the knowledge, which belongs to this collective interest, in proportion as its industry is combined with science, will be its influence on the well-being and safety of society. It is of the first importance, therefore, that education should here exert its most extensive power, and by elevating the morals, as well as stimulating the enterprise of artisans, give a triumph to intellect over mere physical force, and thus secure one of the most dangerous passes of social life against the irruptions of ignorance, and

popular fury. It is a truth not always sufficiently felt, that science, while it elevates the objects of desire, has, in the same proportion, a tendency to restrain the outbreakings of the bad passions of mankind.

I might remark in the next place, that the pursuit of practical science is not only a source of inexhaustible pleasure, opening new avenues to rank and reputation; but it is at the same time one of the surest foundations of opulence. Mere mechanical labour, from the perpetual competition arising from an increasing population, has a natural tendency to descend in the scale of compensation. But this effect is astonishingly increased, by the constant application of machinery, as a substitute for the labour of man. The perfection of machinery has in this manner, at times, thrown whole classes of artisans out of employment, and compelled them to resort to new pursuits for support. Mere manual skill and dexterity are nothing, when put in competition with the regularity, rapidity, and economy of machinery, working under the guidance of science. Now, it must be obvious, that in proportion as an artisan possesses science, will be his facility in passing from one branch of an art to another; and his ability to command a higher price for his services. His capacity, too, for adopting improvements, and keeping pace with the genius of the age, will, (as has been already hinted) be thus immeasurably increased. So, that in the narrowest and most limited view, there is a positive certainty of gain, by understanding the scientific principles of the art, which we profess.

But this would be a very inadequate view of the

benefits arising from this source. It is the power of science in awakening the dormant energy of genius; in pointing out to it the true means to arrive at great ends; in preventing it from being wasted in visionary schemes, or retarded by clumsy processes; in short, it is the power of science in suggesting the first hint, or striking out the first spark, or directing the unsteady aim, or removing the intermediate obstacles, that constitutes its true value, and perhaps its noblest excellence. Even after the first step is taken, and the first developement of inventive genius assumes shape and body, how many obstacles are to be overcome; how many unexpected difficulties are to be met; how many toilsome days and nights are to be consumed in nice adjustments and minute alterations. It is here, that science may be said to foster and nourish genius; to administer to its wants, and soothe its disquietudes, and animate its inquiries. What logarithms are to the mathematician, knowledge of principles is to the mechanic. It not only abridges the processes of computation, and thus diminishes labour, but it puts him in possession of means and computations, otherwise absolutely beyond the reach of human calculation. After Fulton had securely achieved, in his own opinion, the invention of the steam-boat, months were consumed by him, as I learned from his own lips, in making the necessary calculations upon the resistance of fluids, in order to ascertain what was the best form of the boat, to ensure a successful issue to his experiment. I myself, in the course of my judicial life, have had occasion to learn from witnesses the origin and history, and gradual formation, of

two of the most elegant inventions in our own country; and in both instances the original machine, rude, and unsightly, and cumbrous enough, was brought into court, as the best proof of the first sketch, compared with the last labours of the admirable inventors. I have not the least hesitation in saying, that if either of those extraordinary minds had been originally instructed in the principles of mechanical science, half their labours would have been saved. Sure I am, that one of them would not, with his later acquirements in science, have laid aside for a long time the creation of his own genius, as if in despair, that it could ever attain maturity.

I allude to the card machine of Whittemore, and the nail machine of Perkins. Of the former it would not become me to speak in terms of confident praise, from my own want of the proper knowledge of machinery. But I must confess, that when I first saw it, it seemed to me to be almost an intelligent being, and to do every thing but speak; and whether considered with reference to the simplicity of its means, the accuracy and variety of its operations, or its almost universal capacity for common use, it deserves the highest commendation. Other inventions have since somewhat narrowed the sphere of its operations, and made its celebrity less felt. But I may quote the remark of one of our most ingenious countrymen, who, to a question put to him, what, after two months' examination of the patent office at Washington, and his own surveys elsewhere, appeared to him the most interesting of American inventions, unhesitatingly answered, Whittemore's card machine. The remark was made by

Perkins; and perhaps no person, but himself, would have thought, that his own nail machine, which with its toggle-joint consumes bars of iron, and returns them in nails, with the tranquil grandeur of a giant, conscious of superior power, might not have borne the most strenuous rivalry.

And this leads me to remark, in the next place, as matter of pride, as well as of encouragement, that to mechanics themselves we are indebted for some of the most useful and profitable inventions of our age. I have already adverted to the perfection of the steam-engine by Watt. The cotton-machine of Arkwright constitutes an era in inventions, and has already thrown back upon Asia all her various fabrics, and compelled her to yield up to European skill the cheapest labour of her cheapest population. The inventions of Wedgewood have led to almost as striking a rivalry of the pottery and wares of the East. The cotton-gin, which has given to the cotton-growing States of the south their present great staple, is the production of the genius of Whitney. In the year 1794, the Carolinas and Georgia were scarcely known to our ablest diplomatists, as cultivators of the plant, so obscure and unimportant were its results. The invention of Whitney at once gave it the highest value; and laid the broad foundation of their present wealth and prosperity. At this very moment, New England annually consumes, in her manufactories, more than one fifth part of the eight hundred and fifty thousand bales of cotton, the annual produce of their soil! which but for him would have had no existence. What wonders were accomplished by the self-taught architect, Brindley, himself a humble mill-wright;

and yet of such vast compass of thought, that to him rivers seemed of no use, but to feed navigable canals, and the ocean itself but a large reservoir for water-works. What effects is our own Perkins producing by one only of his numerous inventions, the art of softening steel, so as to admit of engraving, and then hardening it again, so as to retain the fine point and polish of copper-plate, without the constant wear of the latter, and its consequent tendency to depreciation? He has enabled us, as it were, to stereotype, and multiply, to an almost incalculable extent, the most beautiful specimens of the art, and cheapen them, so to bring them within the reach of the most moderate fortunes. Many other illustrious instances of genius, successfully applied to the improvement of the arts, might be selected from the work-shops and common trades of life. But in most of these instances it will be found, that the discovery was not the mere result of accident, but arose from the patient study of principles, or from hints gathered from a scientific observation of nice and curious facts. And it may be added, that in all of these instances, in proportion as the inventors acquired a knowledge of the principles of the arts, their genius assumed a wider play, and accomplished its designs with more familiar power and certainty. It is a subject of most profound interest, to observe to what grand results a common principle in mechanics, or an apparently insulated fact, may conduct us, under the guidance of a man of genius. The rule, for instance, in geometry, that the circumferences of circles are in proportion to their diameters, lies at the foundation of most of the operations of practical mechanics, and

has led to the means of increasing mechanical power to an almost incalculable extent. The lever, the pulley, and the wheel, are but illustrations of it. So, too, the habit of nice observation of facts, (the almost constant attendant upon scientific acquirements) has led to surprising conjectures, which have ended in the demonstration of equally surprising truths. Let me avail myself of one or two illustrations, which have been already noticed by others, as better to my purpose, than any which my own memory could furnish. In the course of Sir Isaac Newton's experiments to ascertain the laws of optics, he was led, from the peculiar action of the diamond upon light, to express an opinion that it was carbon, and capable of ignition, and not belonging to the class of crystals. That conjecture has in our day been established, by chemical experiments, to be a fact. He made the discovery also of the compound nature of light, and that its white colour arises from a mixture of all the various colours. This has led to various ingenious improvements in the formation of the lenses of telescopes, by which modern astronomy has been able to display the heavens in new beauty and order. When Franklin, by close observation, had established the identity of lightning with the electric spark, he was immediately led to the practical application of his discovery, by ascertaining the relative conducting power of various substances, so as to guard our dwellings from its tremendous agency. The galvanic battery, to which we are indebted for so many discoveries in chemistry, owes its origin to an apparently trivial circumstance. The discoverer's attention was drawn to an investigation of the cause of the

twitching of a dead frog's leg; and by patient and laborious experiments, he was at length conducted to the discovery of animal electricity.

The polarization of light, as it is called, that is, the fact that rays of light have different sides, which have different properties of reflection, is a discovery in optics of very recent date, which, it is said, "is so fertile in the views it lays open of the constitution of natural bodies, and the minuter mechanism of the universe, as to place it in the very first rank of physical and mathematical science." It was discovered by the French philosopher, Malus, as late as in 1810, by various minute and delicate experiments, and has already led to very extraordinary results.

Indeed, such is the quickening power of science, that it is scarcely possible, that its simplest germ should be planted in the human mind, without expanding into a healthy growth. It generates, as it moves on, new thoughts, and new inquiries, and is forever gathering without exhaustion, and without satiety. The curiosity, which is once awakened by it, never sleeps; the genius, which is once kindled at its altar, burns on with an inextinguishable flame.

It has been remarked, that such was the progress of astronomical science, and the number of minds engaged in it towards the close of the seventeenth century, that if Sir Isaac Newton had never lived, his splendid and invaluable discoveries must have been in the possession of the succeeding age. The approaches had been so near, that they almost touched the very verge of the paths, which

his genius explored, and demonstrated with such matchless ability. If this were true in respect to that branch of physical science, it is far more strikingly true in respect to mechanics. The struggle here in respect to priority of inventions, is often so very close, that a single day sometimes decides the controversy.

It is from considerations of this nature;—that, what has been, must continue to be; that art is never perfect, and nature is inexhaustible; that science, while it is the master of art, is itself ultimately dependent upon it; that the intellectual power grows up in all stations, and in all soils; that, all other circumstances equal, he, who knows and practices, must forever take the lead of him, who merely knows, and has none of the skill to apply power, or the practical sagacity to overcome difficulties; that he, whose interest is indissolubly connected with his science, and who feels at every turn the animating impulse of reward, as well as the pleasure of speculation, and the desire of fame, has more enduring and instant motives for exertion, than he who merely indulges his leisure, or his curiosity; —it is, I say, from these considerations, that I deduce the conclusion, that when the artisan and the mechanic shall have become instructed in science, the inventions of this class will be more numerous, more useful, more profitable, and more ingenious, than those of any other class, and even perhaps of all other classes of society.

What an animating prospect does this afford! What noble ends to poor, neglected, suffering genius! What constant comfort to cheer the hard hours of labour, and the heavier hours of despondency! Much less of success

in life is in reality dependent upon accident, or what is called luck, than is commonly supposed. Far more depends upon the objects, which a man proposes to himself; what attainments he aspires to; what is the circle, which bounds his vision and his thoughts; what he chooses, not *to be educated for*, but to *educate himself for;* whether he looks to the end and aim of the whole of life, or only to the present day or hour; whether he listens to the voice of indolence or vulgar pleasure, or to the stirring voice in his own soul, urging his ambition on to the highest objects. If his views are low and grovelling; if the work-shop, in its cold routine of duties, bounds all his wishes, and his hopes, his destiny is already fixed; and the history of his whole life may be read, though the blush of youth still lingers in his cheeks. It is not a tale merely twice told; it has been told for millions. If, on the other hand, he aspires to be a man, in dignity, independence, spirit, and character, and to give his talents their full scope and vigour; if, to a steady devotion to the practice of his art, he adds a scientific study of its processes and principles, his success is as sure, as any thing on this side of the grave can be. He may even go further, and dream of fame; and if he possess the sagacity of genius, may build a solid immortality upon the foundation of his own inventions.

And why should it not be so? Why should not our youth, engaged in the mechanic arts, under the auspices of institutions like this, reach such a noble elevation of purpose? America has hitherto given her full proportion of genius to the cultivation of the arts. She has never

been behind the most intelligent portions of the world in her contributions of useful inventions for the common good. There are some circumstances in the situation and character of her population, which afford a wider range for talent and inquiry, than in any other country. The very equality of condition; the natural structure of society; the total demolition of all barriers against the advancement of talent from one department of life to another; the non-existence of the almost infinite subdivisions of labour, by which, though more perfection in the result is sometimes obtained, the process has an almost uniform tendency to reduce human beings to mere machines; the mildness of the government; the general facility of subsistence; the absence of all laws regulating trades, and obstructing local competition; these, and many other causes, and especially our free schools, and our cheap means of education, offer to ingenuous youth the most inviting prospects to expand and cultivate their intellectual powers. Under such circumstances, is it too much to prophecy, that hereafter America may take the lead in mechanical improvements, and give another bright example to the world, by the demonstration of the truth, that free governments are as well adapted to perfect the arts of life, and foster inventive genius, as they are to promote the happiness and independence of mankind.

There are no real obstacles in the way, which may not be overcome by ordinary diligence and perseverance. A few hours, saved every week from those devoted to idle pleasure, or listless indolence, would enable every artisan to master, in a comparatively short time, the ele-

mentary principles of the arts. He would have the constant benefit of refreshing his recollection by the practical application of them, and receive the demonstration, at the same time that he was taught the truth. He would find, that the acquisitions of every day added a new facility for future improvement; and that his own mind, quickened and fertilized by various stores of thought, would soon turn that into the truest source of enjoyment, which at first was the minister of toil and anxiety. Consider for a moment what must be the immediate effects of the general adoption of a system of mutual instruction. How powerfully would it work by way of encouragement to laudable ambition. How irresistibly to an increase of skill, and sagacity in the most common employments of life. Ask yourselves what would be the result of one hundred thousand minds engaged at the same moment in the study of mechanical science, and urged on by the daily motives of interest, to acquire new skill, or invent new improvements. It seems to me utterly beyond the reach of human imagination to embody the results, to which such a constant discipline of the intellect, strengthened by the daily experience of the work-shop, would conduct us. The slightest spark of intelligence, (if I may borrow a figure from the arts) would be blown into a steady flame, and the raw material of genius be kindled by a spontaneous combustion into the most intense light.

Gentlemen, I will detain you no longer. The remarks, which I have addressed to you, have been unavoidably of a loose and desultory nature. They have been thrown together, not in the abundance of my leisure, but of my

labours; in the midst of private cares, and many pressing public duties. Such as they are, I trust they may receive your indulgence, if not for their intrinsic value, at least as my small tribute to the merit of this Institution. If I had possessed more leisure, I should have preferred to have given you, as a more suitable topic for an introductory discourse, some account of the rise and progress of the more important arts and inventions in modern times. A close survey of the difficulties overcome, and the triumphs achieved by mechanical genius, would, after all, constitute the most valuable commentary upon the powers of the human mind, and the most encouraging lesson in the study of science.

I conclude with the reflection naturally arising from the subject, that as the true end of philosophy is to render us wiser and happier, so its tendency is to warm our hearts, and elevate our affections, and make us in the highest sense religious beings. When we contemplate the physical creation, and observe, from the minutest atom up to the highest intelligence, continual displays of infinite wisdom, power, and goodness; when we trace out by the light of science the laws, which govern the material world, and observe the order and harmony, and wonderful adaptation of all, from those, which form the sparkling diamond in the mine, or prepare the vollied lightning, or generate the terrific earthquake, or direct the motions of the ocean, up to those, which hold the planets in their spheres; when we turn our thoughts within us, and endeavour to learn what we ourselves are; and consider the nature and capacities of our minds, and feel the divinity, as it were,

stir within us; when we look abroad at the curious displays of human invention in the arts and arrangements of life; and see how man has acquired dominion over the earth and the sea, and the air and the water; how is it possible, I say, when we contemplate such things, not to look up with awe, and admiration, and gratitude, to the First Great Cause of all these blessings. How is it possible not to feel, that we are an emanation of that eternal Spirit, which formed and fashioned us, and breathed into us a rational soul. How is it possible not to read for ourselves a higher destiny, where our powers shall be permitted to expand in endless progression, and continually witness new wonders of the divine perfection. Surely, in the contemplation of such things, we may well exclaim,

"Great and marvellous are thy works, Lord God Almighty; in wisdom thou hast made them all."

MR. WEBSTER'S

INTRODUCTORY LECTURE,

BEFORE THE

MECHANICS' INSTITUTION.

I appear before you, gentlemen, for the performance of a duty, which is, in so great a degree, foreign to my habitual studies and pursuits, that it may be presumptuous in me to hope for a creditable execution of the task. But I have not allowed considerations of this kind to weigh against a strong and ardent desire to signify my approbation of the objects, and my conviction of the utility, of this institution; and to manifest my prompt attention to whatever others may suppose to be in my power, to promote its respectability, and to further its designs.

The Constitution of the Association declares its precise object to be, "Mutual Instruction in the Sciences, as connected with the Mechanic Arts."

The distinct purpose is to connect science, more and more, with art; to teach the established, and invent new, modes of combining skill with strength; to bring the power of the human understanding in aid of the physical powers of the human frame; to facilitate the co-operation of the mind with the hand; to augment convenience, lighten labour, and mitigate toil, by stretching the do-

minion of mind, farther and farther, over the elements of nature, and by making those elements, themselves, submit to human rule, follow human bidding, and work together for human happiness.

The visible and tangible creation, into which we are introduced at our birth, is not, in all its parts, fixed and stationary. Motion, or change of place, regular or occasional, belongs to all or most of the things, which are around us. Animal life every where moves; the earth itself has its motion, and its complexities of motion; the ocean heaves and subsides; rivers run lingering or rushing, to the sea; and the air which we breathe moves and acts with mighty power. Motion, thus pertaining to the physical objects which surround us, is the exhaustless fountain, whence philosophy draws the means, by which, in various degrees, and endless forms, natural agencies and the tendencies of inert matter, are brought to the succour and assistance of human strength. It is the object of mechanical contrivance to modify motion, to produce it in new forms, to direct it to new purposes, to multiply its uses,—by means of it to do better, that which human strength could do without its aid,—and to perform that, also, which such strength, unassisted by art, could not perform.

Motion itself is but the result of force; or, in other words, force is defined to be whatever tends to produce motion. The operation of forces, therefore, on bodies, is the broad field which is open for that philosophical examination, the results of which it is the business of mechanical contrivance to apply. The leading forces or sources

of motion are, as is well known, the power of animals, gravity, heat, the winds, and water. There are various others of less power, or of more difficult application. Mechanical philosophy, therefore, may be said to be, that science which instructs us in the knowledge of natural moving powers, animate or inanimate; in the manner of modifying those powers, and of increasing the intensity of some of them by artificial means, such as heat and electricity; and in applying the varieties of force and motion, thus derived from natural agencies, to the arts of life. This is the object of mechanical philosophy. None can doubt, certainly, the high importance of this sort of knowledge, or fail to see how suitable it is to the elevated rank and the dignity of reasoning beings. Man's grand distinction is his intellect, his mental capacity. It is this, which renders him highly and peculiarly responsible to his Creator. It is this, on account of which the rule over other animals is established in his hands; and it is this, mainly, which enables him to exercise dominion over the powers of nature, and to subdue them to himself.

But it is true, also, that his own animal organization gives him superiority, and is among the most wonderful of the works of God on earth. It contributes to cause, as well as prove, his elevated rank in creation. His port is erect, his face towards heaven, and he is furnished with limbs which are not absolutely necessary to his support or locomotion, and which are at once powerful, flexible, capable of innumerable modes and varieties of action, and terminated by an instrument of wonderful, heavenly workmanship,—the human hand. This marvellous physical

conformation, gives man the power of acting, with great effect, upon external objects, in pursuance of the suggestions of his understanding, and of applying the results of his reasoning power to his own purposes. Without this particular formation he would not be man, with whatever sagacity he had been endowed. No bounteous grant of intellect, were it the pleasure of heaven to make such grant, could raise any of the brute creation to an equality with the human race. Were it bestowed on the Leviathan, he must remain, nevertheless, in the element where alone he could maintain his physical existence. He would still be but the inelegant, misshapen inhabitant of the ocean, "wallowing unwieldy, enormous in his gait." Were the Elephant made to possess it, it would but teach him the deformity of his own structure, the unloveliness of his frame, though "the hugest of things," his disability to act on external matter, and the degrading nature of his own physical wants, which lead him to the deserts, and give him for his favourite home the torrid plains of the tropics. It was placing the King of Babylon sufficiently out of the rank of human beings, though he carried all his reasoning faculties with him, when he was sent away, to eat grass like an ox. And this may properly suggest to our consideration, what is undeniably true, that there is hardly a greater blessing conferred on man than his natural wants. If he had wanted no more than the beasts, who can say how much more than they, he would have attained? Does he associate, does he cultivate, does he build, does he navigate? The original impulse to all these, lies in his wants. It proceeds from the necessities

of his condition, and from the efforts of unsatisfied desire. Every want not of a low kind, physical as well as moral, which the human breast feels, and which brutes do not feel and cannot feel, raises man, by so much, in the scale of existence, and is a clear proof, and a direct instance, of the favour of God towards his so much favoured human offspring. If man had been so made as to have desired nothing, he would have wanted almost every thing worth possessing.

But doubtless the reasoning faculty, the mind, is the leading characteristic attribute of the human race. By the exercise of this, he arrives at the knowledge of the properties of natural bodies. This is science, properly and emphatically so called. It is the science of pure mathematics; and in the high branches of this science lies the true sublime of human acquisition. If any attainment deserve that epithet, it is the knowledge, which, from the mensuration of the minutest dust of the balance, proceeds on the rising scale of material bodies, every where weighing, every where measuring, every where detecting and explaining the laws of force and motion, penetrating into the secret principles which hold the universe of God together, and balancing world against world, and system against system. When we seek to accompany those, who pursue their studies at once so high, so vast and so exact; when we arrive at the discoveries of Newton, which pour in day on the works of God, as if a second *fiat* for light had gone forth from his own mouth;—when, further, we attempt to follow those, who set out where Newton paused, making his goal their

starting place, and proceeding with demonstration upon demonstration, and discovery upon discovery, bring new worlds, and new systems of worlds within the limits of the known universe, failing to learn all only because all is infinite; however we say of man, in admiration of his physical structure, that "in form and moving he is express and admirable," it is here, and here without irreverence, we may exclaim, "in apprehension how like a God!" The study of the pure mathematics will of course not be extensively pursued in an institution, which, like this, has a direct practical tendency and aim. But it is still to be remembered, that pure mathematics lie at the foundation of mechanical philosophy, and that it is ignorance only, which can speak or think of that sublime science as useless research or barren speculation.

It has already been said that the general and well known agents, usually regarded as the principal sources of mechanical powers, are, gravity, acting on solid bodies, the fall of water, which is but gravity acting on fluids, air, heat, and animal strength. For the useful direction and application of the four first of these, that is, of all of them which belong to inanimate nature, some intermediate apparatus, or contrivance, becomes necessary; and this apparatus, whatever its form, is a machine. A machine is an invention for the application of motion, either by changing the direction of the moving power, or by rendering a body in motion capable of communicating a motion greater or less than its own to other bodies, or by enabling it to overcome a power of greater intensity or force than its own. And it is usually said that every

machine, however apparently complex, is capable of being resolved into some one or more of those single machines, of which, according to one mode of description, there are six, and according to another, three, called the mechanical powers. But because machinery, or all mechanical contrivance, is thus capable of resolution into a few elementary forms, it is not to be inferred that science, or art, or both together, though pressed with the utmost force of human genius, and cultivated by the last degree of human assiduity, will ever exhaust the combinations into which these elementary forms may be thrown. An indefinite, though not an infinite reach of invention may be expected; but indefinite, also, if not infinite, are the possible combinations of elementary principles. The field, then, is vast and unbounded. We know not, to what yet unthought of heights the power of man over the agencies of nature may be carried. We only know, that the last half century has witnessed an amazingly accelerated progress in useful discoveries, and that at the present moment, science and art are acting together, with a new companionship, and with the most happy and striking results. The history of mechanical philosophy, is, of itself, a very interesting subject, and will doubtless be treated in this place fully, and methodically, by stated lecturers.

It is a part of the history of man, which, like that of his domestic habits and daily occupations, has been too unfrequently the subject of research; having been thrust aside by the more dazzling topics of war and political revolutions. We are not often conducted by historians within the houses or huts of our ancestors, as they were

centuries ago, and made acquainted with their domestic utensils and domestic arrangements. We see too little, both of the conveniences and inconveniences of their daily and ordinary life. There are, indeed, rich materials for interesting details on these particulars, to be collected from the labours of Goguet and Beckmann, Henry and Turner; but, still, a thorough and well written history of those inventions in the mechanic arts, which are now commonly known, is a *desideratum* in literature.

Human sagacity, stimulated by human wants, seizes first on the nearest natural assistant. The power of his own arm, is an early lesson among the studies of primitive man. This is animal strength; and from this he rises to the conception of employing, for his own use, the strength of other animals. A stone, impelled by the power of his arm, he finds will produce a greater effect than the arm itself; this is a species of mechanical power. The effect results from a combination of the moving force with the gravity of a heavy body. The limb of a tree is a rude, but powerful instrument; it is a lever. And the mechanical powers being all discovered, like other natural qualities, by induction, (I use the word as Bacon used it,) or experience, and not by any reasoning *a priori*, their progress has kept pace with the general civilization and education of nations. The history of mechanical philosophy, while it strongly illustrates, in its general results, the force of the human mind, exhibits, in its details, most interesting pictures of ingenuity struggling with the conception of new combinations, and of deep, intense, and powerful thought, stretched to its utmost to find out, or

deduce, the general principle from the indications of particular facts. We are now so far advanced beyond the age when the principal, leading, important mathematical discoveries were made, and they have become so much matter of common knowledge, that it is not easy to feel their importance, or be justly sensible what an epoch in the history of science each constituted. The half frantic exultation of Archimedes, when he had solved the problem respecting the crown of Hiero, was on an occasion and for a cause certainly well allowing very high joy. And so also was the duplication of the cube.

The altar of Apollo at Athens, was a square block or cube, and to double it required the duplication of the cube. This was a process involving an unascertained mathematical principle. It was quite natural, therefore, that it should be a traditional story, that by way of atoning for some affront to that god, the oracle commanded the Athenians to *double his altar;* an injunction, we know, which occupied the keen sagacity of the Greek geometricians for more than half a century, before they were able to obey it. It is to the great honor, however, of this inimitable people, the Greeks, a people whose genius seems to have been equally fitted for the investigations of science and the works of imagination, that the immortal Euclid, centuries before our era, composed his Elements of Geometry; a work which, for two thousand years, has been, and still continues to be, a text-book for instruction in that science.

A history of mechanical philosophy, however, would not begin with Greece. There is a wonder beyond Greece.

Higher up in the annals of mankind, nearer, far nearer, to the origin of our race, out of all reach of letters, beyond the sources of tradition, beyond all history, except what remains in the monuments of her own art, stands Egypt, the mother of nations! Egypt! Thebes! the Labyrinth! the Pyramids! Who shall explain the mysteries, which these names suggest? The Pyramids! Who can inform us, whether it was by mere numbers, and patience, and labor, aided perhaps by the simple lever; or if not, by what forgotten combination of power, by what now unknown machines, mass was thus aggregated to mass, and quarry piled on quarry, till solid granite seemed to cover the earth and reach the skies?

The ancients discovered many things, but they left many things also to be discovered; and this, as a general truth, is what our posterity, a thousand years hence, will be able to say, doubtless, when we and our generation shall be recorded also among the ancients. For, indeed, God seems to have proposed his material universe, as a standing, perpetual study to his intelligent creatures; where, ever learning, they can yet never learn all; and if that material universe shall last till man shall have discovered all that is unknown, but which, by the progressive improvement of his faculties he is capable of knowing, it will remain through a duration beyond human measurement, and beyond human comprehension.

The ancients knew nothing of our present system of arithmetical notation; nothing of algebra, and of course nothing of the important application of algebra to geometry. They had not learned the use of logarithms, and

were ignorant of fluxions. They had not attained to any just mode for the mensuration of the earth; a matter of great moment to astronomy, navigation, and other branches of useful knowledge. It is scarcely necessary to add, that they were ignorant of the great results which have followed the developement of the principle of gravitation.

In the useful and practical arts, many inventions and contrivances, to the production of which the degree of ancient knowledge would appear to us to have been adequate, and which seem quite obvious, are yet of late origin. The application of water, for example, to turn a mill, is a thing not known to have been accomplished at all in Greece, and is not supposed to have been attempted at Rome, till in or near the age of Augustus. The production of the same effect by wind, is a still later invention. It dates only in the seventh century of our era. The propulsion of the saw, by any other power than that of the arm, is treated as a novelty in England, so late as in the middle of the sixteenth century. The Bishop of Ely, Ambassador from the Queen of England to the Pope, says, "he saw, at Lyons, a saw-mill driven with an upright wheel, and the water that makes it go, is gathered into a narrow trough, which delivereth the same water to the wheels. This wheel hath a piece of timber put to the axletree end, like the handle of a *brock*, (a hand organ,) and fastened to the end of the saw, which being turned with the force of water, hoisteth up and down the saw, that it continually eateth in, and the handle of the same is kept in a rigall of wood, from severing. Also the timber lieth, as it were upon a ladder, which is brought by little

and little to the saw by another vice." From this description of the primitive power-saw, it would seem that it was probably fast only at one end, and that the brock and rigall performed the part of the arm, in the common use of the handsaw.

It must always have been a very considerable object for men to possess, or obtain, the power of raising water, otherwise than by mere manual labor. Yet nothing like the common suction pump has been found among rude nations. It has arrived at its present state only by slow and doubtful steps of improvement; and, indeed, in that present state, however obvious and unattractive, it is something of an abstruse and refined invention. It was unknown in China, until Europeans visited the "Celestial Empire;" and is still unknown in other parts of Asia, beyond the pale of European settlements, or the reach of European communication. The Greeks and Romans are supposed to have been ignorant of it, in the early times of their history; and it is usually said to have come from Alexandria, where physical science was much cultivated by the Greek school, under the patronage of the Ptolemies.

These few and scattered historical notices, gentlemen, of important inventions, have been introduced only for the purpose of suggesting that there is much which is both curious and instructive in the history of mechanics; and that many things which to us, in our state of knowledge, seem so obvious as that we should think they would at once force themselves on men's adoption, have, nevertheless, been accomplished slowly and by painful efforts.

But if the history of the progress of the mechanical arts be interesting, still more so, doubtless, would be the exhibition of their present state, and a full display of the extent to which they are now carried. This field is much too wide even to be entered, on this occasion. The briefest outline even, would exceed its limits; and the whole subject will regularly fall to hands much more able to sustain it. The slightest glance, however, must convince us that mechanical power and mechanical skill, as they are now exhibited in Europe and America, mark an epoch in human history, worthy of all admiration. Machinery is made to perform what has formerly been the toil of human hands, to an extent that astonishes the most sanguine, with a degree of power to which no number of human arms is equal, and with such precision and exactness as almost to suggest the notion of reason and intelligence in the machines themselves. Every natural agent is put unrelentingly to the task. The winds work, the waters work, the elasticity of metals work; gravity is solicited into a thousand new forms of action; levers are multiplied upon levers; wheels revolve on the peripheries of other wheels; the saw and the plane are tortured into an accommodation to new uses, and, last of all, with inimitable power, and "with whirlwind sound," comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent comprised, in the short compass of fifty years! Every where practicable, every where efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to

Briareus. Steam is found, in triumphant operation, on the seas; and under the influence of its strong propulsion, the gallant ship,

> "Against the wind, against the tide,
> Still *steadies*, with an upright keel."

It is on the rivers, and the boatman may repose on his oars; it is in highways, and begins to exert itself along the courses of land conveyance; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artizans, "Leave off your manual labor, give over your bodily toil; bestow but your skill and reason to the directing of my power, and I will bear the toil,—with no muscle to grow weary, no nerve to relax, no breast to feel faintness." What further improvements may still be made in the use of this astonishing power, it is impossible to know, and it were vain to conjecture. What we do know, is, that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible. If its power were now to be annihilated, if we were to miss it on the water and in the mills, it would seem as if we were going back to rude ages.

This society, then, gentlemen, is instituted for the purpose of further and further applying science to the arts, at a time when there is much of science to be applied. Philosophy and the Mathematics have attained to high degrees, and still stretch their wings, like the Eagle.

Chymistry, at the same time, acting in another direction, has made equally important discoveries, capable of a direct application to the purposes of life. Here, again, within so short a period as the lives of some of us, almost all that is known has been learned. And while there is this aggregate of science, already vast, but still rapidly increasing, offering itself to the ingenuity of mechanical contrivance, there is a corresponding demand for every work and invention of art,—produced by the wants of a rich, an enterprising and an elegant age. Associations like this, therefore, have materials to work upon, ends to work for, and encouragement to work.

It may not be improper to suggest, that not only are the general circumstances of the age favorable to such institutions as this, but that there seems a high degree of propriety that one or more should be established here, in the metropolis of New England. In no other part of the country, is there so great a concentration of mechanical operations. Events have given to New England the lead, in the great business of domestic manufactures. Her thickened population, her energetic free labor, her abundant falls of water, and various other causes, have led her citizens to embark, with great boldness, into extensive manufactures. The success of their establishments depends, of course, in no small degree, upon the perfection to which machinery may be carried. Improvement in this, therefore, instead of being left to chance or accident, is justly regarded as a fit subject of assiduous study. The attention of our community is, also, at the present moment, strongly attracted towards the construction of canals, rail-

ways, dry docks, and other important public works. Civil engineering is becoming a profession, offering honorable support and creditable distinction to such as may qualify themselves to discharge its duties. Another interesting fact is before us. New taste and a new excitement are evidently springing up in our vicinity, in regard to an art, which as it unites in a singular degree, utility and beauty, affords inviting encouragements to genius and skill. I mean Architecture. Architecture is military, naval, sacred, civil, or domestic. Naval architecture, certainly, is of the highest importance to a commercial and navigating people, to say nothing of its intimate and essential connexion, with the means of national defence. This science should not be regarded as having already reached its utmost perfection. It seems to have been some time in a course of rapid advancement. The building, the rigging, the navigating of ships, have, to every one's conviction, been subjects of great improvement within the last fifteen years. And where, rather than in New England, may still further improvements be looked for? Where is ship building either a greater business, or pursued with more skill and eagerness?

In civil, sacred, and domestic architecture, present appearances authorise the strongest hopes of improvement. These hopes rest, among other things, on unambiguous indications of the growing prevalence of a just taste. The principles of architecture are founded in nature, or good sense, as much as the principles of epic poetry. The art constitutes a beautiful medium, between what belongs to mere fancy, and what belongs entirely to the exact

sciences. In its forms and modifications, it admits of infinite variation, giving broad room for invention and genius; while, in its general principles, it is founded on that which long experience and the concurrent judgment of ages have ascertained to be generally pleasing. Certain relations, of parts to parts, have been satisfactory to all the cultivated generations of men. These relations constitute what is called *proportion*, and this is the great basis of architectural art. This established proportion is not to be *followed* merely because it is ancient, but because its use, and the pleasure which it has been found capable of giving to the mind, through the eye, in ancient times, and modern times, and all civilized times, prove that its principles are well founded, and just; in the same manner that the Iliad is proved, by the consent of all ages, to be a good poem.

Architecture, I have said, is an art that unites, in a singular manner, the useful and the beautiful. It is not to be inferred from this, that every thing in architecture is beautiful, or is to be so esteemed, in exact proportion to its apparent utility. No more is meant, than that nothing which evidently thwarts utility, can or ought to be accounted beautiful; because, in every work of art, the design is to be regarded, and what defeats that design, cannot be considered as well done. The French rhetoricians have a maxim, that in literary composition, "nothing is beautiful which is not true." They do not intend to say, that strict and literal truth is alone beautiful in poetry or oratory; but they mean that, that which grossly offends against probability, is not in good taste, in either. The same relation subsists between beauty and utility in archi-

tecture, as between truth and imagination in poetry. Utility is not to be obviously sacrificed to beauty, in the one case; truth and probability are not to be outraged for the cause of fiction and fancy, in the other. In the severer styles of architecture, beauty and utility approach, so as to be almost identical. Where utility is more strongly than ordinary the main design, the proportions which produce it, raise the sense or feeling of beauty, by a sort of reflection or deduction of the mind. It is said that ancient Rome had, perhaps, no finer specimens of the classic Doric, than were in the sewers which ran under her streets, and which were of course always to be covered from human observation; so true is it, that cultivated taste is always pleased with justness of proportion; and that design, seen to be accomplished, gives pleasure. The discovery and fast increasing use of a noble material, found in vast abundance, nearer to our cities than the Pentelican quarries to Athens, may well awaken, as they do, new attention to architectural improvement. If this material be not entirely well suited to the elegant Ionic, or the rich Corinthian, it is yet fitted, beyond marble, beyond perhaps almost any other material, for the Doric, of which the appropriate character is strength, and for the Gothic, of which the appropriate character is grandeur.

It is not more than justice, perhaps, to our ancestors, to call the Gothic the English, classic architecture; for in England, probably, are its most distinguished specimens. As its leading characteristic is grandeur, its main use would seem to be sacred. It had its origin, indeed, in ecclesiastical architecture. Its evident design was to surpass

the ancient orders, by the size of the structure and its far greater heights; to excite perceptions of beauty, by the branching traceries and the gorgeous tabernacles within; and to inspire religious awe and reverence by the lofty pointed arches;—the flying buttresses, the spires, and the pinnacles, springing from beneath, stretching upwards towards the heavens with the prayers of the worshippers. Architectural beauty having always a direct reference to utility, edifices, whether civil or sacred, must of course undergo different changes, in different places, on account of climate, and in different ages, on account of the different states of other arts, or different notions of convenience. The hypethral temple, for example, or temple without a roof, is not to be thought of in our latitudes; and the use of glass, a thing not now to be dispensed with, is also to be accommodated, as well as it may be, to the architectural structure. These necessary variations, and many more admissible ones, give room for improvements to an indefinite extent, without departing from the principles of true taste. May we not hope, then, to see our own city celebrated as the city of architectural excellence? May we not hope, to see our native granite reposing in the ever during strength of the Doric, or springing up in the grand and lofty Gothic, in forms which beauty and utility, the eye and the judgment, taste and devotion, shall unite to approve and to admire? But while we regard sacred and civil architecture as highly important, let us not forget that other branch, so essential to personal comfort and happiness,—domestic architecture, or common house building. In ancient times, in all gov-

ernments, and under despotic governments in all times, the convenience or gratification of the monarch, the government or the public, has been allowed too often, to put aside considerations of personal and individual happiness. With us, different ideas happily prevail. With us, it is not the public, or the government, in its corporate character, that is the only object of regard. The public happiness is to be the aggregate of the happiness of individuals. Our system begins with the individual man. It begins with him when he leaves the cradle; and it proposes to instruct him in knowledge and in morals, to prepare him for his state of manhood; on his arrival at that state, to invest him with political rights, to protect him, in his property and pursuits, and in his family and social connexions; and thus to enable him to enjoy as an individual, moral, and rational being, what belongs to a moral and rational being. For the same reason, the arts are to be promoted for their general utility, as they effect the personal happiness and well being of the individuals who compose the community. It would be adverse to the whole spirit of our system, that we should have gorgeous and expensive public buildings, if individuals were at the same time to live in houses of mud. Our public edifices are to be reared by the surplus of wealth, and the savings of labor, after the necessities and comforts of individuals are provided for; and not, like the Pyramids, by the unremitted toil of thousands of half starved slaves. Domestic architecture, therefore, as connected with individual comfort and happiness, is to hold a first place in the esteem of our artists. Let our citizens have houses cheap, but comfortable; not

gaudy, but in good taste; not judged by the portion of earth which they cover, but by their symmetry, their fitness for use, and their durability.

Without farther reference to particular arts, with which the objects of this society have a close connexion, it may yet be added, generally, that this is a period of great activity, of industry, of enterprise in the various walks of life. It is a period, too, of growing wealth, and increasing prosperity. It is a time when men are fast multiplying, but when means are increasing still faster than men. An auspicious moment, then, it is, full of motive and encouragement, for the vigorous prosecution of those inquiries, which have for their object the discovery of farther and farther means of uniting the results of scientific research to the arts and business of life.

AN ESSAY

ON THE

IMPORTANCE TO PRACTICAL MEN OF SCIENTIFIC KNOWLEDGE,

AND ON THE

ENCOURAGEMENTS TO ITS PURSUIT.

BY EDWARD EVERETT.

*** The following Essay is compiled from a discourse delivered by the author, at the opening of the Mechanics' Institute in Boston, in November, 1827; an address before the Middlesex County Lyceum, at Concord, in November, 1829; and an oration before the Columbian Institute at Washington, in January, 1830. The publication of those addresses, at the time of their delivery, was requested, but was delayed on the ground that they formed, severally, parts of a general view of the subject, which it was the intention of the author to complete at some future period. That intention has been fulfilled, as far as it was in the power of the author, in the following Essay, which is respectfully dedicated to the associations before whom the above-mentioned addresses were delivered.

THE object of the Mechanics' Institute is, to diffuse useful knowledge among the mechanic class of the community. It aims, in general, to improve and inform the minds of its members; and particularly to illustrate and explain the principles of the various arts of life, and render them familiar to those, who are to exercise these arts as their occupation in society. It is also a proper object of the Institute to point out the connection between the mechanic arts and the

other pursuits and occupations, and show the foundations, which exist in our very nature, for a cordial union between them all.

These objects recommend themselves strongly and obviously to general approbation. While the cultivation of the mind, in its more general sense, and in connection with morals, is as important to the mechanics as to any other class of the community; nothing is plainer than that those whose livelihood depends on the skilful practice of the arts, ought to be instructed, as far as possible, in the scientific principles and natural laws, on which the arts are founded. This is necessary, in order that the arts themselves should be pursued to the greatest advantage; that popular errors should be eradicated; that every accidental improvement in the processes of industry, which offers itself, should be readily taken up and pursued to its principle; that false notions, leading to waste of time and labor, should be prevented from gaining or retaining currency; in short, that the useful, like the ornamental arts of life, should be carried to the point of attainable perfection.

The history of the progress of the human mind shows us, that, for want of a diffusion of scientific knowledge among practical men, great evils have resulted both to science and practice. Before the invention of the art of printing, the means of acquiring and circulating knowledge were few and ineffectual. The philosopher was, in consequence, exclusively a man of study, who, by living in a monastic seclusion, and by delving into the few books which time had spared,—particularly the works of Aristotle and his commentators,—succeeded in mastering the learning of the day;

learning mostly of an abstract and metaphysical nature. Thus, living in a world not of practice, but speculation, never bringing his theories to the test of observation, all his studies assumed a visionary character. Hence the projects for the transmutation of metals; a notion not originating in any observation of the qualities of the different kinds of metals, but in reasoning, *a priori*, on their supposed identity of substance. So deep-rooted was this delusion, that a great part of the natural science of the middle ages consisted in projects to convert the baser metals into gold. It is plain that such a project would no more have been countenanced by intelligent, well informed persons, practically conversant with the nature of the metals, than a project to transmute pine into oak, or fish into flesh.

In like manner, by giving science wholly up to the philosophers, and making the practical arts of life merely a matter of traditionary repetition from one generation to another of uninformed artisans, much evil of an opposite kind was occasioned. Accident, of course, could be the only source of improvement; and for want of acquaintance with the leading principles of mechanical philosophy, the chances were indefinitely multiplied against these accidental improvements. For want of the diffusion of information among practical men, the improvements prevailing in an art in one place were unknown in other places; and processes existing at one period were liable to be forgotten in the lapse of time. Secrets and mysteries, easily kept in such a state of things, and cherished as a source of monopoly by those who possessed them, were so common, that *mystery* is still occasionally used as synonymous with *trade*. This also contributed

to the loss of arts once brought to perfection, such as that of staining glass, as practised in the middle ages. Complicated machinery was out of the question; for it requires, for its invention and improvement, the union of scientific knowledge and practical skill. The mariner was therefore left to creep along the coast, while the astronomer was casting nativities; and the miner was reduced to the most laborious and purely mechanical processes, to extract the precious metals from the ores that really contained them, while the chemist, who ought to have taught him the method of amalgamation, could find no use for mercury, but as a menstruum by which baser metals could be turned into gold.

At the present day, this state of things is certainly changed. A variety of popular treatises and works of reference have made the great principles of natural science generally accessible. It certainly is in the power of almost every one, by pains and time properly bestowed, to acquire a decent knowledge of every branch of practical philosophy. But still it would appear, that, even now, this part of education is not on the right footing. Generally speaking, even now, all actual instruction in the principles of natural science is confined to the colleges; and the colleges are, for the most part, frequented only by those intended for professional life. The elementary knowledge of science, which is communicated at the colleges, is indeed useful in any and every calling; but it does not seem a proper arrangement, that none but those intended for the pulpit, the bar, or the profession of medicine, should receive instruction in those principles, which regulate the operation of the mechanical pow-

ers, and lie at the foundation of complicated machinery; which relate to the navigation of the seas, the smelting and refining of metals, the composition and improvement of soils, the reduction to a uniform whiteness of the vegetable fibre, the mixture and application of colors, the motion and pressure of fluids in large masses, the nature of light and heat, the laws of magnetism, electricity and galvanism. It would seem that this kind of knowledge was more immediately requisite for those who are to construct or make use of labor-saving machinery, who are to navigate the ocean, to lay out and direct the excavation of canals, to build steam-engines and hydraulic presses, to work mines, and to conduct large agricultural and manufacturing establishments. Hitherto, with some partial exceptions, little has been done to afford to those engaged in these pursuits that knowledge, which, however convenient to others, would seem essential to them. There has been scarce any thing, which could be called education for practical life; and those persons, who, in the pursuit of any of the useful arts, have signalized themselves by the application of scientific principles for the invention of new processes or the improvement of the old, have been self-educated men.

I am aware that it is often objected, that the greatest discoveries and inventions have been either the production of such self-educated men, or have been struck out by accident. There certainly is some truth in this. So long as no regular system of scientific education for the working classes exists, it is a matter of necessity, that, if any great improvement be made, it must be either the result of accident or the happy thought of some powerful native genius, which

forces its way, without education, to the most astonishing results. This, however, is no more the case with respect to the useful arts and the mechanical pursuits, than with respect to all the other occupations of society; and it would continue to be the case after the establishment of the best system of scientific education. We find, in every pursuit and calling, some instances of remarkable men, who, without an early education adapted to the object, have raised themselves to great eminence. Lord Chancellor King, in England, was a grocer at that period of life which is commonly spent in academical study, by those destined for the profession of the law. Chief Justice Pratt, of New York, having been brought up a carpenter, was led by a severe cut from an axe, which unfitted him for work, to turn his attention to the law. Franklin, who seemed equally to excel in the conduct of the business of life, in the sublimest studies of philosophy, and in the management of the most difficult state affairs, was bred a printer.—All these callings are quite respectable, but no one would think of choosing either of them as the school of the lawyer, judge, or statesman. The fact that the native power of genius sometimes forces its way against all obstacles, and under every discouragement, proves nothing as to the course which it is expedient for the generality of men to pursue. The safe path to excellence and success, in every calling, is that of appropriate preliminary education, diligent application to learn the art, and assiduity in practising it. And I can perceive no reason why this course should not be followed in reference to the mechanical, as well as the professional callings. The instances of eminent men like those named, and many others that might be, such as Arkwright

and Harrison, who have sprung from the depths of poverty, to astonish and benefit mankind, no more prove that education is useless to the mechanic, than the corresponding examples prove that it is useless to the statesman, jurist or divine.

Besides, it will perhaps be found, that the great men, like those I have named, instead of being instances to show that education is useless, prove only, that occasionally men, who commence their education late, are as successful as those who commence it early. This shows, not that an early education is no benefit, but that the want of it may sometimes be made up in later years. It might be so made up, no doubt, oftener than it is; and it is in this country much more frequently than in any other.

The foundation of a great improvement is also often a single conception, which suggests itself occasionally to strong and uneducated minds; and who have the good fortune afterwards to receive from others that aid, in executing their projects, without which the most promising conception might have perished undeveloped. Thus Sir Richard Arkwright was a poor barber, endowed, however, with a wonderful quickness of mind. What particular circumstances awakened his mechanical taste we are not told. There is some reason to think, that this, like other strongly-marked aptitudes, may partly depend on the peculiar organization of the body, which is exactly the same in no two men. The daily observation of the operation of the spinning wheel, in the cottages of the peasantry of Lancashire, gave him a full knowledge of the existing state of the art, which it was his good fortune to improve to a degree which is even yet the

wonder of the world. He conceived, at length, the idea of an improved machine for spinning. And in this conception,—not improbably a flash across the mind, the work of an instant,—lay all his original merit. But this is every thing. America was discovered from the moment that Columbus firmly grasped the idea that, the earth being spherical, the Indies might be reached by sailing on a westerly course. If the actual discovery had not been made for ages after the death of Columbus, he would, nevertheless, in publishing this idea to the world, have been the pilot that led the way, whoever had followed his guidance. Sir Richard Arkwright, having formed the conception of his spinning machine, had recourse to a watchmaker to execute his idea. But how rarely could it happen, that circumstances would put it in the power of a person ignorant, and poor, to engage the co-operation of an intelligent watchmaker!

Neither is it intended, that the education which we recommend, should extend to a minute acquaintance with the practical application of science to the details of every art. This would be impossible, and does not belong to preparatory education. We wish only that the general laws and principles should be so taught, as greatly to multiply the number of persons competent to carry forward such casual suggestions of improvement as may present themselves, and to bring their art to that state of increasing excellence, which all arts reach by long-continued, intelligent cultivation.

It may further be observed, with respect to those great discoveries which seem to be produced by happy accidents and fortuitous suggestion, that such happy accidents are most likely to fall in the way of those, who are on the look out for

them,—those whose mental eyesight has been awakened and practised to behold them. The world is informed of all the cases in which such fortunate accidents have led to useful and brilliant results; but their number would probably appear smaller than it is now supposed to be, were such a thing possible as the *negative history* of discovery and improvement. No one can tell us what might have been done, had every opportunity been faithfully improved; every suggestion sagaciously caught up and followed out. No one can tell how often the uneducated or unobservant mind has approached to the very verge of a great discovery, has had some wonderful invention almost thrust upon it, but without effect. The ancients, as we learn from many passages in the Greek and Latin classics, were acquainted with convex lenses, but did not apply them to the construction of magnifying glasses or telescopes. They made use of seal-rings containing inscriptions; and they marked their flocks with brands, containing the owner's name. In each of these practices, faint rudiments of the art of printing are concealed. Cicero, in one of his moral works (*De Natura Deorum*), in confuting the errors of those philosophers, who taught that the world was produced by the fortuitous concourse of wandering atoms, uses the following language, as curious in connection with the point I would illustrate, as it is beautiful in expression, and powerful in argument:—"Here," says he, "must I not wonder, if there should be a man who can persuade himself, that certain solid and separate bodies are borne about by force or weight, and that this most beautiful and finished world is formed by their accidental meeting? Whoever can think this possible, I do not see why he cannot also believe that,

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if a large number of *forms* of the one and twenty letters (of gold or any like substance) were thrown anywhere together, that the annals of Ennius might be made out from them, as they are cast on the ground, so as to be read in order; a thing which I know not if it be within the power of chance to effect, even in a single verse."—How very near an approach is made, in this remark, to the invention of the art of printing, fifteen hundred years before it took place!

How slight and familiar was the occurrence which gave to Sir Isaac Newton the first suggestion of his system of the universe! This great man had been driven by the plague from London to the country, and had left his library behind him. Obliged to find occupation in the activity of his own mind, he was led, in his meditations, to trace the extent of the principle which occasioned the fall of an apple from the tree, in the garden where he passed his solitary hours. Commencing with this familiar hint, he followed it out to that universal law of gravity, which binds the parts of the earth and ocean together, which draws the moon to the earth, the satellites to the planets, the planets to the sun, and the sun itself, with its attendant worlds, toward some grand and general point of attraction for that infinity of systems, of which the several stars are the centres. How many hundreds of thousands of men, since the creation of the world, had seen an apple falling from a tree! How many philosophers had speculated profoundly on the system of the universe! But it required the talent of a man, placed by general consent at the head of the human race, to deduce from this familiar occurrence, on the surface

of the earth, the operation of the primordial law of nature which governs the glorious movements of the heavens, and holds the universe together. Nothing less than his sagacity could have made the deduction, and nothing less than a mathematical skill and an acquaintance with the previously ascertained principles of science,—such as falls to the lot of very few,—would have enabled Newton to demonstrate the truth of his system.

Let us quote another example, to show that the most obvious and familiar facts may be noticed for ages without effect, till they are observed by a sagacious eye, and scrutinized with patience and perseverance.—The appearance of lightning in the clouds was as old as creation; and certainly no natural phenomenon forces itself more directly on the notice of men. The existence of the electric fluid, as excited by artificial means, was familiarly known to philosophers a hundred years before Franklin; and there are a few vague hints, prior to his time, that lightning was an electrical appearance. But it was left for Franklin distinctly to conceive that proposition, and to institute an experiment by which it should be demonstrated. The process by which he reached this great conclusion is worth remembering. Dr. Franklin had seen the most familiar electrical experiments performed at Boston, in 1745, by a certain Dr. Spence, a Scotch lecturer. His curiosity was excited by witnessing these experiments, and he purchased the whole of Dr. Spence's apparatus, and repeated the experiments at Philadelphia. Pursuing his researches with his own instruments, and others which had been liberally presented to the province of Pennsylvania, by the proprietor, Mr. Penn,

and by Dr. Franklin's friend Mr. Collinson, our illustrious countryman rapidly enlarged the bounds of electrical science, and soon arrived at the undoubting conviction, that the electric fluid and lightning are identical. But he could not rest till he had brought this truth to the test of demonstration, and he boldly set about an experiment, upon the most terrific element in nature. He at first proposed, by means of a spire, which was erecting in Philadelphia, to form a connection between the region of the clouds and an electrical apparatus; but the appearance of *a boy's kite* in the air, suggested to him a readier method. Having prepared a kite adapted for the purpose, he went out into a field, accompanied by his son, to whom alone he had imparted his design. The kite was raised, having a key attached to the lower end of the cord, and being insulated by means of a silken thread, by which it was fastened to a post. A heavy cloud, apparently charged with lightning, passed over the kite; but no signs of electricity were witnessed in the apparatus. Franklin was beginning to despair, when he saw the loose fibres bristling from the hempen cord. He immediately presented his knuckle to the key, and received the electrical spark. Overcome by his feelings, at the consummation of this great discovery, "he heaved a deep sigh, and, conscious of an immortal name, felt that he could have been content, had that moment been his last." How easily it might have been his last, was shown by the fact, that when professor Richman, a few months afterwards, was repeating this experiment at St. Petersburgh, a globe of fire flashed from the conducting rod to his forehead, and killed him on the spot.

Brilliant as Dr. Franklin's discoveries in electricity were, and much as he advanced the science by his sagacious experiments and unwearied investigations, a rich harvest of farther discoveries was left by him to the succeeding age. The most extraordinary of these is the discovery of a modification of electricity, which bears the name of the philosopher by whom it was made known to the world;—I refer, of course, to Galvanism. Lewis Galvani was an anatomist in Bologna. On a table in his study lay some frogs, which had been prepared for a broth for his wife, who was sick. An electrical machine stood on the table. A student of Galvani accidentally touched the nerve on the inside of the leg of one of the frogs, and convulsions immediately took place in the body of the animal. Galvani himself was not present at the moment, but this curious circumstance caught the attention of his wife,—a lady of education and talent,—who ascribed it to some influence of the electrical machine. She informed her husband of what had happened, and it was his opinion also that the electrical machine was the origin of the convulsions. A long-continued and patient course of investigation corrected this error, and established the science of Galvanic electricity, nearly as it now exists, and which has proved, in the hands of Sir Humphrey Davy, the agent of the most brilliant and astonishing discoveries. It is well known that frogs have been a common article of food in Europe for ages; but it was only when they were brought by accident into the study of the anatomist, and fell beneath the notice of a sagacious eye, that they became the occasion of this brilliant discovery.

In all these examples, we see that, whatever be the first origin of a great discovery or improvement, science and study are required to perfect and illustrate it. The want of a knowledge of the principles of science has often led men to waste much time on pursuits, which a better acquaintance with those principles would have taught them were hopeless. The patent office in every country, where such an institution exists, contains, perhaps, as many machines, which show the want, as the possession, of sound scientific knowledge. Besides unsuccessful essays at machinery, holding forth a promise of feasibility, no little ingenuity, and much time and money, have been lavished on a project, which seems, in modern times, to supply the place of the philosopher's stone of the alchemists;—I mean a contrivance for perpetual motion, a contrivance inconsistent with the law of gravity. The effect of a familiar acquaintance with the principles of science is not only to guide the mind to the discovery of what is useful and practical, but to protect it from the delusions of an excited imagination, ready to waste itself, in the ardor of youth, enterprise, and conscious ingenuity, on that which the laws of Nature herself have made unattainable.

Such are some of the considerations, which show the general utility of scientific education, for those engaged in the mechanical arts. Let us now advert to some of the circumstances, which ought, particularly in the United States of America, to act as encouragements to the young men of the country to apply themselves earnestly, and, as far as it can be done, systematically, to the attainment of such an education.

1. And, first, it is beyond all question, that what are called the mechanical trades of this country are on a much more liberal footing than they are in Europe. This circumstance not only ought to encourage those who pursue them, to take an honest pride in improvement, but it makes it their incumbent duty to do so. In almost every country of Europe, various restraints are imposed on the mechanics, which almost amount to slavery. A good deal of censure has been lately thrown on the journeymen printers of Paris, for entering into combinations not to work for their employers, and for breaking up the power-presses, which were used by the great employing printers. I certainly shall not undertake to justify any acts of illegal violence and the destruction of property. But when you consider, that no man can be a master printer in France without a license, and that only eighty licenses were granted in Paris, it is by no means wonderful that the journeymen, forbidden by law to set up for themselves, and prevented by the power-presses from getting work from others, should be disposed, after having carried through one revolution for the government, to undertake another for themselves. Of what consequence is it to a man, forbidden by the law to work for his living, whether Charles X or Louis Philip is king?

In England, it is exceedingly difficult for a mechanic to get what is called a settlement, in any town except that in which he was born, or where he served his apprenticeship. The object of imposing these restrictions is to enforce on each parish the maintenance of its native poor; and the resort of mechanics from place to place is permitted only on conditions, with which many of them are unable to comply.

The consequence is, they are obliged to stay where they were born, where perhaps there are already more hands than can find work; and, from the decline of the place, even the established artisans want employment. Chained to such a spot, where chance and necessity have bound him, the young man feels himself but half free. He is thwarted in his choice of a pursuit for life, and obliged to take up with an employment against his preference, because there is no opening in any other. He is depressed in his own estimation, because he finds himself unprotected in society. The least evil likely to befall him is, that he drags along a discouraged and unproductive existence. He more naturally falls into dissipation and vice, or enlists in the army or navy; while the place of his nativity is gradually becoming a decayed, and finally a rotten borough, and, as such, enables some rich nobleman to send two members to parliament, to make laws against combinations of workmen.

In other countries, singular institutions exist, imposing oppressive burdens on the mechanical classes. I refer now more particularly to the corporations, guilds, or crafts, as they are called, that is, the companies formed by the members of a particular trade. These exist, with great privileges, in every part of Europe; in Germany, there are some features in the institution, as it seems to me, peculiarly oppressive. The different crafts in that country are incorporations recognised by law, governed by usages of great antiquity, with a fund to defray the corporate expenses, and, in each considerable town, a house of entertainment is selected as the house of call, or harbor, as it is styled, of each particular craft. Thus you see, in the German towns, a number of taverns indicated

by their signs as the Masons' Harbor, the Blacksmiths' Harbor, &c. No one is allowed to set up as a master workman in any trade, unless he is admitted as a freeman or member of the craft; and such is the stationary condition of most parts of Germany, that I understand that no person is admitted as a master workman in any trade, except to supply the place of some one deceased or retired from business. When such a vacancy occurs, all those desirous of being permitted to fill it present a piece of work, executed as well as they are able to do it, which is called their master-piece, being offered to obtain the place of a master workman. Nominally, the best workman gets the place; but you will easily conceive, that, in reality, some kind of favoritism must generally decide it. Thus is every man obliged to submit to all the chances of a popular election, whether he shall be allowed to work for his bread; and that, too, in a country where the people are not permitted to have any agency in choosing their rulers. But the restraints on journeymen, in that country, are still more oppressive. As soon as the years of apprenticeship have expired, the young mechanic is obliged, in the phrase of the country, to *wander* for three years. For this purpose he is furnished, by the master of the craft in which he has served his apprenticeship, with a duly authenticated wandering book, with which he goes forth to seek employment. In whatever city he arrives, on presenting himself, with this credential, at the house of call, or harbor, of the craft in which he has served his time, he is allowed gratis a day's food and a night's lodging If he wishes to get employment in that place, he is assisted in procuring it. If he does not wish to,

or fails in the attempt, he must pursue his wandering; and this lasts for three years, before he can be anywhere admitted as a master.—I have heard it argued, that this system had the advantage of circulating knowledge from place to place, and imparting to the young artisan the fruits of travel and intercourse with the world. But, however beneficial travelling may be, when undertaken by those who have the taste and capacity to profit by it, I cannot but think, that to compel every young man, who has just served out his time, to leave his home, in the manner I have described, must bring his habits and morals into peril, and be regarded rather as a hardship than as an advantage. There is no sanctuary of virtue like home.

You will see, from these few hints, the nature of some of the restraints and oppressions to which the mechanical industry of Europe is subjected. Wherever governments and corporations thus interfere with private industry, the spring of personal enterprise is unbent. Men are depressed with a consciousness of living under control. They cease to feel a responsibility for themselves, and, encountering obstacles whenever they step from the beaten path, they give up improvement as hopeless. I need not, in the presence of this audience, remark on the total difference of things in America. We are apt to think, that the only thing in which we have improved on other countries, is our political constitution, whereby we choose our rulers, instead of recognising their hereditary right. But a much more important difference between us and foreign countries is wrought into the very texture of our society; it is that generally pervading freedom from restraint, in matters like those

I have just specified. In England, forty days' undisturbed residence in a parish gives a journeyman mechanic a settlement, and consequently entitles him, should he need it, to support from the poor rates of that parish. To obviate this effect, the magistrates are on the alert, and instantly expel a new comer from their limits, who does not possess means of giving security, such as few young mechanics command. A duress like this, environing the young man, on his entrance into life, upon every side, and condemning him to imprisonment for life, on the spot where he is born, converts the government of the country—whatever be its name—into a despotism.

2. There is another consideration, which invites the artisans of this country to improve their minds; it is the vastly wider field, which is opened to them, as the citizens of a new country; and the proportionate call which exists for labor and enterprise in every department. In the old world, society is full. In every country but England, it has long been full. It was in that country not less crowded, till the vast improvements in machinery and manufacturing industry were made, which have rendered it, in reference to manufactures and commerce,—what ours is, still more remarkably, in every thing,—a country of urgent and expansive demand, where new branches of employment are constantly opening, new kinds of talent called for, new arts struck out, and more hands employed in all the old ones. In different parts of our country, the demand is of a different kind, but it is active and stirring every where.

It may not be without use to consider the various causes of this enlargement of the field of action, in this country.

The first, and, perhaps, the main cause, is the great abundance of good land, which lies open, on the easiest conditions, to every man, who wishes to avail himself of it. One dollar and twenty-five cents will enable any man to purchase an acre of first-rate land. This circumstance alone acts like a safety-valve to the great social steam-engine. There can be no very great pressure any where in a community, where, by travelling a few miles into the interior, a man can buy an acre of land for a day's work. This was the first stimulus which applied itself to the condition of things in this country, after the revolutionary war, and it is still operating in full force.

The next great spring to our industry was felt in the navigating interest. This languished greatly under the old confederation, being crushed by foreign competition. The adoption of the constitution breathed the breath of life into it. By the duty on foreign tonnage, and by the confinement of the privilege of an American vessel to an American built ship, our commercial marine sprang into existence with the rapidity of magic, and—under a peculiar state of things in Europe—appropriated to itself the carrying trade of the world.

Shortly after this stimulus was applied to the industry of the Northern and Middle States, the Southern States acquired an equally prolific source of wealth, unexpected and rapid beyond example in its operation; I mean the cultivation of cotton. In 1789, the hope was expressed by southern members of congress, that, if good seed could be procured, cotton might be raised in the Southern States, where, before that time, and for several years after, not a pound had been

raised for exportation. The culture of this beautiful staple was encouraged by a duty of three cents a pound on imported cotton; but it languished for some time, on account of the difficulty of separating the seed from the fibre. At length Mr. Whitney of Connecticut invented the saw-gin; and so prodigiously has this culture increased, that it is calculated, that the cotton crop of last year amounted to one million of bales, of at least 300 lbs. each.

In 1807, the first successful essays were made with steam navigation. The progress at first was slow. In 1817, there was not such a thing as a regular line of steamboats on the Western waters. Two hundred steamboats now ply those waters, and half as many navigate the waters of the Atlantic coast.

The embargo and war created the manufactures of the United States. Before that period, nothing was done, on a large scale, in the way of manufactures. With some fluctuations in prosperity, they have succeeded in establishing themselves on a firm basis. A man can now buy two good shirts, well made, for a dollar. Fifteen years ago, they would have cost him three times that sum.

Still more recently, a system of internal improvements has been commenced, which will have the effect, when a little further developed, of crowding within a few years the progress of generations. Already Lake Champlain from the north, and Lake Erie from the west, have been connected with Albany. The Delaware and Chesapeake Bay have been united. A canal is nearly finished in the upper part of New Jersey, from the Delaware to the Hudson, by which coal is already despatched to our market. Another route

is laid out across the same state, to connect New York by a rail-road with Philadelphia. A water communication has been opened by canals half way from Philadelphia to Pittsburgh. Considerable progress is made both on the rail-road and the canal, which are to unite Baltimore and Washington with the Ohio River. A canal of sixty miles in length is open from Cincinnati to Dayton in the state of Ohio; and another, of more than three hundred miles in extent, to connect Lake Erie with the Ohio, is two thirds completed.

I mention these facts, (which, though among the most considerable, are by no means all of the same character, which might be quoted,) not merely as being in themselves curious and important; though this they are in a high degree. My object is to turn your attention to their natural effect, in keeping up a constant and high demand for labor, art, skill and talent of all kinds, and their accumulated fruits, that is, capital; and thereby particularly inviting the young to exert themselves strenuously to take an active, industrious, and honorable part in a community, which has such a variety of employments and rewards for all its members. The rising generation beholds before it *not* a *crowded* community, but one where labor, both of body and mind, is in greater request, and bears a higher relative price, than in any other country. When it is said that labor is dear in this country, this is not a mere commercial proposition, like those which fill the pages of the price current; but it is a great *moral fact*, speaking volumes as to the state of society, and reminding the American citizen, particularly the young man who is beginning life, that he lives in a country

where every man carries about with him the thing in greatest request; where the labor and skill of the human hands, and every kind of talent and acquisition, possess a relative importance elsewhere unknown—in other words, where an *industrious man* is of the greatest consequence.

These considerations are well calculated to awaken enterprise, to encourage effort, to support perseverance; and we behold on every side that such is their effect.—I have already alluded to the astonishing growth of our navigation after the adoption of the federal constitution. It affords an example, which will bear dwelling upon, of American enterprise, placed in honorable contrast with that of Europe. In Great Britain, and in other countries of Europe, the India and China trade was, and to a great degree still is, locked up by the monopoly enjoyed by affluent companies, protected and patronized by the state, and clothed, themselves, in some cases, with imperial power. The territories of the British East India Company are computed to embrace a population of 115,000,000 souls. The consequence of this state of things was not the activity, but the embarrassment, of the commercial intercourse with the East. Individual enterprise was not awakened. The companies sent out annually their unwieldy vessels of twelve hundred tons burden, commanded by salaried captains, to carry on the commerce, which was secured to them by a government monopoly, and which, it was firmly believed, could not be carried on in any other way. Scarcely was American independence declared, when our moderate-sized merchant vessels, built with economy, and navigated with frugality, doubled both the great capes of the world. The north-western coast of America

began to be crowded. Not content with visiting old markets, our intelligent ship-masters explored the numerous islands of the Indian Archipelago. Vessels from Salem and Boston, of two and three hundred tons, went to ports in those seas, that had not been visited by a foreign ship since the days of Alexander the Great. The intercourse between Boston and the Sandwich Islands was uninterrupted. A man would no more have thought of boasting that he had been round the world, than that he had been to Liverpool. After Lord Anson and Captain Cook had, by order and at the expense of the British government, made their laborious voyages of discovery and exploration in the Pacific Ocean, and on the coast of America, it still remained for a merchant-vessel from Boston to discover and enter the only considerable river, that flows into the Pacific, from Behring's Strait to Cape Horn. Our fellow citizen, Captain Gray, piloted the British admiral Vancouver into the Columbia River; and, in requital of this service, the British government now claims jurisdiction over it, partly on the ground of prior discovery!

This is but a single instance of the propitious effect on individual enterprise of the condition of things under which we live. But the work is not all done; it is, in fact, hardly begun. This vast continent is as yet no where fully stocked,—almost every where thinly peopled. There are yet mighty regions of it, in which the settler's axe has never been heard. These remain, and portions of them will long remain, open for coming generations, a sure preservative against the evils of a redundant population on the seaboard. The older parts of the country, which have been settled by

the husbandman, and reclaimed from the state of nature, are now to be settled again by the manufacturer, the engineer, and the mechanic. First settled by a civilized, they are now to be settled by a dense population. Settled by the hard labor of the human hands, they are now to be settled by the labor-saving arts, by machinery, by the steam engine, and by internal improvements. Hitherto the work to be done was that, which nothing but the tough sinews of the arm of man could accomplish. This work, in most of the old states, and some of the new ones, has been done, and is finished. It was performed under incredible hardships, fearful dangers, with heart-sickening sacrifices, amidst the perils of savage tribes, and of the diseases incident to a soil, on which deep forests, for a thousand years, had been laying their deposit, and which was now for the first time opened to the sun. The kind, the degree, the intensity of the labor, which has been performed by the men who settled this country, have, I am sure, no parallel in history. I believe that if a thrifty European farmer from Norfolk in England or Flanders, a vine-dresser from Burgundy, an olive gardener from Italy—under the influence of no stronger feelings than those which actuate the mass of the stationary population of those countries—were set down in a North American forest, with an axe on his shoulder, and told to get his living, that his heart would fail him at the sight. What has been the slow work of two thousand years in Europe, has here been effected in two hundred, unquestionably under the cheering moral stimulus of our free institutions. We have now, in some parts of the United States, reached a point in our progress, where, to a considerable degree, a new

form of society will appear; in which the wants of a settled country and a comparatively dense population will succeed to those of a thin population, scattered over a soil as yet but partially reclaimed. We shall henceforth feel, more and more, the want of improved means of communication. We must, in every direction, have turnpikes, unobstructed rivers, canals, rail-roads, and steamboats. The mineral treasures of the earth, metals, coals, ochres, fine clay, limestone, gypsum, salt, are to be brought to light, and applied to the purposes of the arts, and the service of man. Another immense capital, which nature has invested for us in the form of water power, (a natural capital, which I take to be fully equal to the steam capital of Great Britain,) is to be turned to account, by being made to give motion to machinery. Still another vast capital, lying unproductive, in the form of land, is to be realized; and no small part of it, for the first time, by improved cultivation. All the manufactures are to be introduced on a large scale; the coarser—where it has not been done—without delay; and the finer, in rapid succession, and in proportion to the acquisition of skill, the accumulation of capital, and the improvement of machinery. With these will grow up, or increase, the demand for various institutions for education; the call for every species of intellectual service; the need for every kind of professional assistance,—all increased by a political organization, of itself in the highest degree favorable to the creation and diffusion of energy throughout the commonwealth.

These are so many considerations, which call on the rising generation of those destined for the active and mechani-

cal arts, *to improve their minds*. It is only in this manner, that they can effectually ascertain the true bent of their own faculties, and, having ascertained it, employ themselves with greatest success in the way for which Providence has fitted them. It is only in this manner that they can make themselves highly respected in society, and secure to themselves the largest share of those blessings, which are the common objects of desire. In most of the countries of the older world, the greatest part of the prizes of life are literally distributed by the lottery of birth. Men are born to wealth, which they cannot alienate; to power, from which they cannot, without a convulsion of the body politic, be removed; or to poverty and depression, from which, generally speaking, they cannot emerge. Here it rarely happens, that, even for a single generation, an independence can be enjoyed without labor and diligence bestowed on its acquisition and preservation; while, as a general rule, the place to which each individual shall rise in society is precisely graduated on the scale of capacity and exertion—in a word, of merit. Every thing, therefore, that shows the magnitude and growth of the country,—its abundance and variety of resources,—its increasing demand for all the arts, both of ornament and utility,—is another reason, calling upon the emulous young men of the working classes to enter into the career of improvement, where there is the fullest scope for generous competition, and every talent of every kind is sure to be required, honored, and rewarded.

There is another reflection, which ought not to be omitted. The rapid growth and swift prosperity of the country have their peculiar attendant evils, in addition to those in-

separable from humanity. To resist the progress of these evils, to provide, seasonably and efficaciously, the moral and reasonable remedy of those disorders of the social system, to which it may be more particularly exposed, is a duty to be performed by the enlightened and virtuous portion of the mass of the community, quite equal in importance to any other duty, which they are called to discharge. In Europe, it is too much the case, that the virtuous influenees, which operate on the working classes, come down from the privileged orders, while the operatives themselves, as they are called, are abandoned to most of the vices of the most prolific source of vice—ignorance. It is of the utmost importance, in this country, that the active walks of life should be filled by an enlightened class of men, with a view to the security and order of the community, and to protect it from those evils, which have been thought, in Europe, to be inseparable from the great increase of the laboring population. What is done in other countries by *gens d'armes* and horse-guards, must here be done by public sentiment, or not at all. It is an enlightened moral public sentiment, that must spread its wings over our dwellings, and plant a watchman at our doors. It is perfectly well known to all who hear me, that, as a class, the mechanic and manufacturing population of Europe is regarded as grossly depraved; while the agricultural population—with as little exception—is set down as incurably stupid. This conviction was so prevalent, that many of the most patriotic of *our* citizens were opposed to the introduction of manufactures among us, partly on the ground that factories are necessarily seminaries of vice and immorality. Thus far, this fear has been

most happily relieved by experience; and it is found that those establishments are as little open to reproach, on the score of morals, as any other in the community. Our mechanic and agricultural population will, in this part of the country, support the comparison, for general intelligence and morality, with any in the world. This state of things, if it can be rendered permanent, is a great social triumph, and will be to America a juster subject of self-gratulation than any thing belonging merely to the political, economical, and physical growth of the community. It deserves the consideration of every patriot, that the surest way of perpetuating and diffusing this most enviable state of things—this most desirable of all the advantages, which we can have over the old world—is to multiply the means of improving the mind, and put them within the reach of all classes. An intelligent class can scarce ever be, as a class, vicious; never, as a class, indolent. The excited mental activity operates as a counterpoise to the stimulus of sense and appetite. The new world of ideas; the new views of the relations of things; the astonishing secrets of the physical properties and mechanical powers, disclosed to the well informed mind, present attractions, which—unless the character is deeply sunk—are sufficient to counterbalance the taste for frivolous or corrupt pleasures; and thus, in the end, a standard of character is created in the community, which, though it does not invariably save each individual, protects the virtue of the mass.

3. I am thus brought to the last consideration, which I shall mention, as an encouragement to the mechanic classes to improve their minds; and that is, the comparatively high-

er rank which our institutions assign to them in the political system. One of the great causes, no doubt, of the enterprise and vigor which have already distinguished our countrymen, in almost every pursuit, is the absence of those political distinctions, which are independent of personal merit and popular choice. It is the strongest motive that we can suggest, for unremitted diligence in the acquisition of useful knowledge, on the part of the laborious classes, that they have a far more responsible duty to discharge to society than ever devolved on the same class in any other community. Every book of travels, not less than every opportunity of personal observation, instructs us of the deplorable ignorance of a great part of those by whom the work of the community is done, in foreign countries. In some parts of England, this class is more enlightened than it is on the continent of Europe; and in that country, great efforts are making, at the present time,—and particularly through the instrumentality of institutions like that under the auspices of which we are now assembled,—to extend the means of education to those who have hitherto been deprived of them. But it is a party question among them, not how far it is right and proper, but how far it is prudent and safe to enlighten the people; and while the liberal party in England are urgent for the diffusion of useful knowledge, to prevent the people from breaking out into violence and revolution, the government party exclaim against a farther diffusion of knowledge, as tending to make the people discontented with their condition. I remember to have seen, not long since, a charge to the grand jury by a very eminent English judge, in which the practice of boxing is com-

mended, and the fear is expressed, that popular education has been pushed too far.

The man who should, in this country, express a doubt whether the education of the people foreboded ill to the state, would merely be regarded as wanting common judgment and sagacity. We are not only accustomed to that state of things, but we regard it as our great blessing and privilege, to which the higher orders in Europe look forward, as the fearful result of bloody revolutions. The representative system, and our statute of distributions, are regarded by us, not as horrors consequent upon a convulsion of society, but as the natural condition of the body politic.

This condition of the country, however, is not to be regarded merely as a topic of lofty political declamation. Its best effects are, and must be, those which are not immediately of a political character. If the mass of the people behold no privileged class placed invidiously above them; if they choose those who make and administer the laws; if the extent of public expenditure is determined by those who bear its burden,—this surely is well; but if the mass of the people here were what it is in most parts of Europe, it may be doubted whether such a system would not be too good for them. Who would like to trust his life and fortune to a Spanish jury or a Neapolitan jury? Under the reign of Napoleon, an attempt was made to introduce the trial by jury, not only into France, but into some of the dependent kingdoms. It has been stated, that when the peasants of some of these countries were impanneled in the jury-box, they not only considered it an excessively onerous and irksome duty, but showed themselves utterly in-

capable of discharging it, with sufficient discretion and intelligence.

The great use, then, to be made of popular rights should be popular improvement. Let the young man, who is to gain his living by his labor and skill, remember that be is a citizen of a free state; that on him and his contemporaries it depends, whether he will be happy and prosperous himself in his social condition, and whether a precious inheritance of social blessings shall descend, unimpaired, to those who come after him; that there is no important difference in the situation of individuals, but that which they themselves cause, or permit to exist; that if something of that inequality in the goods of fortune, which is inseparable from human things, exist in this country, it ought to be viewed only as another excitement to that industry, by which, nine times out of ten, wealth is acquired; and still more to that cultivation of the mind, which, next to the moral character, makes the great difference between man and man. The means are already ample and accessible; and it is for the majority of the community, by a tax, of which the smallest proportion falls on themselves, to increase these means to any desirable extent.

These remarks apply with equal force to almost every individual. There are some considerations, which address themselves more exclusively to the ardent mind emulous of the praise of excelling. Such cannot realize too soon, that we live in an age of improvement; an age in which investigation is active and successful in every quarter; and in which what has been effected, however wonderful, is but the brilliant promise of what may further be done. The

important discoveries, which have been made in almost every department of human occupation, speculative and practical, within less than a century, are almost infinite. To speak only of those which minister most directly to the convenience of man—what changes have not been already wrought in the condition of society, what addition has not been made to the wealth of nations, and the means of private comfort, by the inventions, discoveries and improvements of the last hundred years? High in importance among these are the increased facilities for transportation. By the use of the locomotive steam-engine upon a rail-road, passengers and merchandise may now be conveyed from place to place, at the rate of fifteen and even twenty miles an hour. Although not to be compared with this, the plan of M'Adam is eminently useful, consisting, as it does, of a method, by which a surface as hard as a rock can be carried along, over any foundation, at an expense not much greater, and, under some circumstances, not at all greater, than that of turnpike roads on the old construction. By the chemical process of bleaching, what was formerly done by exposure to the sun and air for weeks, is now done under cover, in a few days. By the machinery for separating the seed from the staple of cotton, the value of every acre of land, devoted to the culture of this most important product, has, to say the least, been doubled. By the machinery for carding, spinning and weaving cotton, the price of a yard of durable cotton cloth has been reduced from a half a dollar to a few cents. Lithography and stereotype printing are probably destined to have a very important influence in enlarging the sphere of the operations of the press. By

the invention of gas lights, an inflammable air, yielding the strongest and purest flame, is extracted in a laboratory, and conducted under ground all over a city, and brought up wherever it is required, in the street, in the shop, in the dwelling-house. The safety-lamp enables the miner to walk unharmed through an atmosphère of explosive gas. And, last and chiefest, the application of steam, as a général moving power, is rapidly extending its effects from one branch of industry to another, from one interest to another, of the community, and bids fair, within no distant period, to produce the most essential changes in the social condition of the world. All these beautiful, surprising, and most useful discoveries and improvements, have been made within less than a century; most of them within less than half that time.

What must be the effect of this wonderful multiplication of ingenious and useful discoveries and improvements? Undoubtedly *this*, that, in addition to all their immediate beneficial consequences, they will lead to further discoveries and still greater improvements. Of that vast system, which we call Nature, and of which none but its Author can comprehend the whole, the laws and the properties, that have as yet been explored, unquestionably form but a few parts connected with a grand succession of parts yet undiscovered, by an indissoluble although an unseen chain. Each new truth that is found out, besides its own significance and value, is a step to the knowledge of further truth, leading off the inquisitive mind on a new track, and upon some higher path; in the pursuit of which new discoveries are made, and the old brought into new and unexpected connections.

The history of human science is a collection of facts, which, while it proves the connection with each other of truths and arts, at first view remote and disconnected, encourages us to scrutinize every department of knowledge, however trite and familiar it may seem, with a view to discovering its relation with the laws and properties of nature, comprehended within it, but not yet disclosed. The individual, who first noticed the attractive power of magnetic substances, was gratified, no doubt, with observing a singular and inexplicable property of matter, which he may have applied to some experiments rather curious than useful. The man, who afterwards observed the tendency of a magnetized body toward the poles of the earth, unfolded a far more curious and important law of nature, but one which, resting there, was productive of no practical consequences. Then came the sagacious, or most fortunate person, who, attaching the artificial magnet to a traversing card, contrived the means of steering a vessel in the darkest night across the high seas. To him we cannot suppose that the important consequences of his discovery were *wholly* unperceived; but since, in point of history, near two centuries passed away before they began to be developed, we can hardly suppose that the inventor of the mariner's compass caught more than a glimpse of the nature of his invention. The Chinese are supposed to have been acquainted with it, as also with the art of printing, from time immemorial, without having derived from either any of those results, which have changed the aspect of modern Europe. Then came Columbus. Guided by the faithful pilot, who watches when the eye of man droops,—the patient little

steersman, whom darkness does not blind, nor the storm drive from his post,—Columbus discovered a new world;—a glorious discovery, as he, no doubt, felt it to be, both in anticipation and achievement. But it does not appear, that even Columbus had indulged a vision more brilliant than that of a princely inheritance for his own family, and a rich colony for Spain;—a vision fulfilled in his own poverty and chains, and in the corruption and degeneracy of the Spanish monarchy. And yet, from his discovery of America, so disastrous to himself and country, have sprung, directly or indirectly, most of the great changes of the political, commercial and social condition of man in modern times. It is curious, also, to reflect, that as the Chinese, from time immemorial, (as has just been remarked,) have possessed the mariner's compass and the art of printing, to little purpose; so they, or some people in their neighborhood, on the northeastern coast of Asia, either with the aid of the compass, or merely by coasting from island to island, appear to have made the discovery of America, on the western side of the continent, a thousand years before it was discovered by Columbus, on the eastern side, without, however, deriving from this discovery any beneficial consequences to the old world or the new. It was left for the spirit of civilization, awakened in western Europe toward the close of the fifteenth century, to develope, and put in action, the great elements of power and light, latent in this discovery. Its first effect was the establishment of the colonial system, which, with the revolution in the financial state of Europe, occasioned by the opening of the American mines, gave, eventually, a new aspect to both hemispheres. What the

sum total of all these consequences has been, may be partly judged from the fact, that the colonization of the United States was but one of them. The further extension of adventures of discovery was facilitated by new scientific inventions and improvements. The telescope was contrived, and, from the more accurately observed movements of the heavenly bodies, tables of longitude were constructed, which gave new confidence to the navigator. He now visits new shores, lying under different climates, whose productions, transplanted to other regions, or introduced into the commerce of the world, give new springs to industry, open new sources of wealth, and lead to the cultivation of new arts. It is unnecessary to dwell on particulars; but who can estimate the full effect on social affairs of such products as sugar, coffee, tea, rice, tobacco, the potato, cotton, indigo, the spices, the dye-woods, the mineral and fossil substances, newly made to enter into general use and consumption; the discovery, transportation and preparation of which are so many unforeseen effects of former discoveries. Each of these, directly or indirectly, furnished new materials for mind to act upon; new stimulus to its energies. Navigation, already extended, receives new facilities from the use of the chronometer. The growing wealth of the community increases the demand for all the fabrics of industry; the wonderful machinery for carding, spinning, and weaving, is contrived; water and vapor are made to do the work of human hands, and almost of human intellect; as the cost of the fabric decreases, the demand for it multiplies geometrically, and furnishes an ever-growing reward for the exertions of the ever-active spirit of im-

provement. Thus a mechanical invention may leaa to a geographical discovery; a physical cause to a political or an intellectual effect. A discovery results in an art; an art produces a comfort; a comfort, made cheaply accessible, adds family on family to the population; and a family is a new creation of thinking, reasoning, inventing and discovering beings. Thus, instead of arriving at the end, we are at the beginning of the series, and ready to start, with recruited numbers, on the great and beneficent career of useful knowledge.

What, then, are these great and beneficial discoveries, in their origin? What is the process which has led to them? They are the work of rational man, operating upon the materials existing in nature, and observing the laws and properties of the physical world. The Creator of the universe has furnished us the material; it is all around us, above us, and beneath us; in the ground under our feet; the air we breathe; the waters of the ocean and of the fountains of the earth; in the various subjects of the kingdoms of nature. We cannot open our eyes, nor stretch out our hands, nor take a step, but we see, and handle, and tread upon the things, from which the most wonderful and useful discoveries and inventions have been deduced. What is gunpowder, which has changed the character of modern warfare? It is the mechanical mixture of some of the most common and least costly substances. What is the art of printing? A contrivance less curious, as a piece of mechanism, than a musical box. What is the steam-engine? An apparatus for applying the vapor of boiling water. What is vaccination? A trifling ail, communicated

by a scratch of the lancet, and capable of protecting human life against one of the most dreadful maladies to which it is exposed.

And are the properties of matter all discovered? its laws all found out? the uses to which they may be applied all detected? I cannot believe it. We cannot doubt, that truths now unknown are in reserve, to reward the patience and the labors of future lovers of truth, which will go as far beyond the brilliant discoveries of the last generation, as these do beyond all that was known to the ancient world. The pages are infinite in that great volume, which was written by the hand divine, and they are to be gradually turned, perused, and announced, to benefited and grateful generations, by genius and patience; and especially by patience; by untiring, enthusiastic, self-devoting patience. The progress which has been made in art and science is indeed vast. We are ready to think a pause must follow; that the goal must be at hand. But there is no goal; and there can be no pause; for art and science are in themselves progressive. They are moving powers, animated principles: they are instinct with life; they are themselves the intellectual life of man. Nothing can arrest them, which does not plunge the entire order of society into barbarism. There is no end to truth, no bound to its discovery and application; and a man might as well think to build a tower, from the top of which he could grasp Sirius in his hand, as prescribe a limit to discovery and invention.

Never do we more evince our arrogant ignorance, than when we boast our knowledge. True Science is modest; for her keen, sagacious eye discerns that there are deep,

undeveloped mysteries where the vain sciolist sees all plain. We call this an age of improvement, as it is. But the Italians, in the age of Leo X, and with great reason, said the same of their age; the Romans, in the time of Cicero, the same of theirs; the Greeks, in the time of Pericles, the same of theirs; and the Assyrians and Egyptians, in the flourishing periods of their ancient monarchies, the same of theirs. In passing from one of these periods to another, prodigious strides are often made; and the vanity of the present age is apt to flatter itself, that it has climbed to the very summit of invention and skill. A wiser posterity at length finds out, that the discovery of one truth, the investigation of one law of nature, the contrivance of one machine, the perfection of one art, instead of narrowing, has widened the field of knowledge still to be acquired, and given, to those who came after, an ampler space, more numerous data, better instruments, a higher point of observation, and the encouragement of living and acting in the presence of a more intelligent age. It is not a century since the number of fixed stars was estimated at about three thousand. Newton had counted no more. When Dr. Herschel had completed his great telescope, and turned it to the heavens, he calculated that two hundred and fifty thousand stars passed through its field in a quarter of an hour!

It may not irreverently be conjectured to be the harmonious plan of the universe, that its two grand elements of mind and matter should be accurately adjusted to each other; that there should be full occupation in the physical world, in its laws and properties, and in the moral and

social relations connected with it, for the contemplative and active powers of every created intellect. The imperfection of human institutions has, as far as man is concerned, disturbed the pure harmony of this great system. On the one hand, much truth, discoverable even at the present stage of human improvement, as we have every reason to think, remains undiscovered. On the other hand, thousands and millions of rational minds, for want of education, opportunity and encouragement, have remained dormant and inactive, though surrounded on every side by those qualities of things, whose action and combination, no doubt, still conceal the sublimest and most beneficial mysteries.

But a portion of the intellect, which has been placed on this goodly theatre, is wisely, intently, and successfully active; ripening, even on earth, into no mean similitude of higher natures. From time to time, a chosen hand, sometimes directed by chance, but more commonly guided by reflection, experiment, and research, touches, as it were, a spring till then unperceived; and, through what seemed a blank and impenetrable wall,—the barrier to all farther progress,—a door is thrown open into some before unexplored hall in the sacred temple of truth. The multitude rushes in, and wonders that the portals could have remained concealed so long. When a brilliant discovery or invention is proclaimed, men are astonished to think how long they had lived on its confines, without penetrating its nature.

It is now a hundred years since it was found out that the vapor of boiling water is, as we now think it, the most powerful mechanical agent within the control of man. And yet, even after the contrivance of the steam-engine on

a most improved construction, and although the thoughts of numerous ingenious mechanicians were turned to the subject, and various experiments made, it was left for our fellow citizen Fulton, in a successful application of this agent, as brilliant as its first discovery, to produce another engine,—the steamboat,—of incalculable utility and power. The entire consequences of this discovery cannot yet be predicted; but there is one prediction relative to it, and that among the first ever made, which has been most calamitously fulfilled. When the interests of Mr. Fulton, under the laws of New York, were maintained by Mr. Emmet at the bar of the legislature of that state, at the close of his argument, he turned to his client, in an affecting apostrophe. After commending the disinterestedness with which he devoted his time, talents and knowledge to enterprises and works of public utility, to the injury of his private fortunes, he added: "Let me remind you, however, that you have other and closer ties. I know the pain I am about to give, and I see the tears I make you shed. But by that love I speak,—by that love, which, like the light of heaven, is refracted in rays of different strength, upon your wife and children, which, when collected and combined, forms the sunshine of your soul;—by that love I do adjure you, provide in time for those dearest objects of your care. Think not I would instil into your mind a mean or sordid feeling; but now, that wealth is passing through your hands, let me entreat you to hoard it while you have it." And then, after sketching the dangers which threatened his interests as guarantied by the laws of the state, Mr. Emmet prophetically added: "Yes, my friend, my heart bleeds while I utter

it, but I have fearful forebodings, that you may hereafter find in public faith a broken staff for your support, and receive from public gratitude a broken heart for your reward." From the time this prediction was uttered, the stupendous consequences of the invention of Fulton have been, every day, more and more amply developed. It has brought into convenient neighborhood with each other some of the remotest settlements on the waters of the United States. It has made the Mississippi navigable up stream as well as down, (which it hardly was before,) incredibly accelerating, in time of peace, the settlement of its mighty valley, and making it henceforth invulnerable in time of war. It has added beyond all estimate to the value of the time, and to the amount of the capital, of a large portion of the population of the country; and, without impairing the importance of these benefits to America, has as signally imparted them, or similar benefits, to Europe, and the rest of the civilized world. While these grand developements of the character of Fulton's invention have been taking place, the life, the estate, the family of the great inventor, have, one after another, been sacrificed and crushed. Within a few months after the eloquent appeal just recited was made, Fulton actually died of disease contracted by exposure in the gratuitous service of the public. In a few years, a decision of the supreme court of the United States scattered the remains of his property to the winds; and twice or thrice, since that period, has an appeal been made to Congress, on behalf of his orphan children, for such a provision as would spare them from the alternative of charity or starvation—and has been made in vain.

But it is time to return to the facts with which I was illustrating the wonderful advances made, from time to time, in the cultivation or application of the most familiar arts. As far back as human history runs, the use of the distaff and loom is known; but it is not yet one hundred years since Sir Richard Arkwright was born; the poor journeyman barber, the youngest of thirteen children, who began and perfected the most important improvements in the machinery for manufacturing cotton, which (as has been stated on the most respectable English authority) "bore the English nation triumphantly through the wars of the French revolution," and are unquestionably of greater value to her than all her colonies, from Hindostan to Labrador.

The ocean which lies between America and Europe may be crossed in a fortnight; but after the fleets of Tyre, of Carthage, of Rome, and of the maritime powers of the middle ages, had been, for thousands of years, accustomed to navigate the sea, it was reserved for a poor Genoese pilot, begging his way from court to court, and by the simple process of sailing on one course as long as he had water to float his ship, to discover a new world.

Our geographical knowledge shows us that we do not, like so many generations of our predecessors, live within the reach of other undiscovered continents; but we do unquestionably live, act, and speculate, within the reach of properties and powers of things, whose discovery and application (when they take place) will effect changes in society, as great as those produced by the magnet, the discovery of America, the art of printing, or the steamboat. We do doubtless live within the reach of undiscovered worlds

of science, art, and improvement. No royal permission is requisite to launch forth on the broad sea of discovery that surrounds us,—most full of novelty where most explored,—and it may yet be reserved for the modest and secluded lover of truth and votary of science, in the solitude of his humble researches, to lay open such laws of matter, as will affect the condition of the civilized world.

This, then, is the encouragement we have to engage in any well conceived enterprise for the diffusion of useful knowledge and the extension of general improvement. Wherever there is a human mind possessed of the common faculties, and placed in a body organized with the common senses, there is an active, intelligent being, competent, with proper cultivation, to the discovery of the highest truths, in the natural, the social, and the political world. It is susceptible of demonstration,—if demonstration were necessary,—that the number of useful and distinguished men, which are to benefit and adorn society around us, will be exactly proportioned, upon the whole, to the means and encouragements to improvement existing in the community; and every thing, which multiplies these means and encouragements, tends, in the same proportion, to the multiplication of inventions and discoveries useful and honorable to man. The mind, although it does not stand in need of high culture, to the attainment of great excellence, does yet stand in need of some culture, and cannot thrive and act without it. When it is once awakened, and inspired with a consciousness of its own powers, and nourished into vigor by the intercourse of kindred minds, either through books or living converse, it does not disdain, but it needs not, fur-

ther extraneous aid. It ceases to be a pupil; it sets up for itself; it becomes a master of truth, and goes fearlessly onward, sounding its way, through the darkest regions of investigation. But it is almost indispensable, that, in some way or other, the elements of truth should be imparted from kindred minds; and if these are wholly withheld, the intellect, which, if properly cultivated, might have soared with Newton to the boundaries of the comet's orbit, is chained down to the wants and imperfections of mere physical life, unconscious of its own capacities, and unable to fulfil its higher destiny.

Contemplate, at this season of the year, one of the magnificent oak trees of the forest, covered with thousands and thousands of acorns. There is not one of those acorns that does not carry within itself the germ of a perfect oak, as lofty and as wide-spreading as the parent stock; which does not enfold the rudiments of a tree that would strike its roots in the soil, and lift its branches toward the heavens, and brave the storms of a hundred winters. It needs for this but a handful of soil, to receive the acorn as it falls, a little moisture to nourish it, and protection from violence till the root is struck. It needs but these; and these it does need, and these it must have; and for want of them, trifling as they seem, there is not one out of a thousand of those innumerable acorns, which is destined to become a tree.

Look abroad through the cities, the towns, the villages of our beloved country, and think of what materials their population, in many parts already dense, and every where rapidly growing, is, for the most part, made up. It is not lifeless enginery, it is not animated machines, it is not brute

beasts, trained to subdue the earth: it is rational, intellectual beings. There is not a mind, of the hundreds of thousands in our community, that is not capable of making large progress in useful knowledge; and no one can presume to tell or limit the number of those who are gifted with all the talent required for the noblest discoveries. They have naturally all the senses and all the faculties—I do not say in as high a degree, but who shall say in no degree?—possessed by Newton, or Franklin, or Fulton. It is but a little which is wanted to awaken every one of these minds to the conscious possession and the active exercise of its wonderful powers. But this little, generally speaking, is indispensable. How much more wonderful an instrument is an eye than a telescope! Providence has furnished this eye; but art must contribute the telescope, or the wonders of the heavens remain unnoticed; and it is for want of the little, that human means must add to the wonderful capacity for improvement born in man, that by far the greatest part of the intellect, innate in our race, perishes undeveloped and unknown. When an acorn falls upon an unfavorable spot, and decays there, we know the extent of the loss;—it is that of a tree, like the one from which it fell;—but when the intellect of a rational being, for want of culture, is lost to the great ends for which it was created, it is a loss which no one can measure, either for time or for eternity.

EVERETT'S

LECTURE

ON THE

WORKING MEN'S PARTY.

MAN is by nature an active being. He is made to labor. His whole organization—mental and physical—is that of a hard-working being. Of his mental powers we have no conception, but as certain capacities of intellectual action. His corporeal faculties are contrived for the same end, with astonishing variety of adaptation.—Who can look only at the muscles of the hand, and doubt that man was made to work? Who can be conscious of judgment, memory, and reflection, and doubt that man was made to act? He requires rest, but it is in order to invigorate him for new efforts;—to recruit his exhausted powers; and as if to show him, by the very nature of rest, that it is Means, not End:—that form of rest, which is most essential and most grateful, sleep, is attended with the temporary suspension of the conscious and active powers. Nature is so ordered as both to require and encourage man to work.—He is created with wants, which cannot be satisfied without labor; at the same time, that ample provision is made by Providence, to satisfy them, with labor.—The plant springs up and grows on the spot, where the seed was cast by accident. It is fed by the

moisture, which saturates the earth or is held suspended in the air; and it brings with it a sufficient covering to protect its delicate internal structure. It toils not, neither doth it spin, for clothing or food.—But man is so created, that, let his wants be as simple as they will, he must labor to supply them. If, as is supposed to have been the case in primitive ages, he lives upon acorns and water, he must draw the water from the spring; and in many places he must dig a well in the soil; and he must gather the acorns from beneath the oak, and lay up a store of them for winter.—He must, in most climates, contrive himself some kind of clothing of barks or skins; must construct some rude shelter; prepare some kind of bed, and keep up a fire.—In short, it is well known, that those tribes of our race, which are the least advanced in civilization, and whose wants are the fewest, have to labor the hardest for their support; but at the same time it is equally true, that in the most civilized countries, by far the greatest amount and variety of work are done; so that the improvement, which takes place in the condition of man, consists, not in diminishing the amount of labor performed, but in enabling men to work more, or more efficiently, in the same time.—A horde of savages will pass a week in the most laborious kinds of hunting; following the chase day after day; their women, if in company with them, carrying their tents and their infant children on their backs; and all be worn down by fatigue and famine; and in the end they will perhaps kill a buffalo. The same number of civilized men and women would probably, on an average, have kept more steadily at work, in their various trades and occupations, but with much less exhaustion; and

the products of their industry would have been vastly greater; or, what is the same thing, much more work would have been done.

It is true, as man rises in improvement, he would be enabled by his arts and machinery, to satisfy the primary wants of life, with less labor; and this may be thought to show, at first glance, that man was not intended to be a working being; because, in proportion as he advances in improvement, less work would be required to get a mere livelihood. But here we see a curious provision of nature. In proportion as our bare natural wants are satisfied, artificial wants, or civilized wants, show themselves. And in the very highest state of improvement, it requires as constant an exertion to satisfy the new wants, which grow out of the habits and tastes of civilized life, as it requires in savage life, to satisfy hunger and thirst, and keep from freezing. In other words, the innate desire of improving our condition keeps us all in a state of want. We cannot be so well off that we do not feel obliged to work, either to ensure the continuance of what we now have, or to increase it.—The man, whose honest industry just gives him a competence, exerts himself, that he may have something against a rainy day;—and how often do we not hear an affectionate father say, he is determined to spare no pains,—to work in season and out of season,—in order that his children may enjoy advantages denied to himself.

In this way, it is pretty plain, that Man, whether viewed in his primitive and savage state, or in a highly improved condition, is a working being. It is his destiny—the law of his nature—to labor. He is made for it,—and he cannot live without it; and the Apostle Paul summed up the mat-

ter, with equal correctness and point, when he said, that "if any would not work, neither should he eat."

It is a good test of principles like these, to bring them to the standard of general approbation or disapprobation. There are, in all countries, too many persons, who, from mistaken ideas of the nature of happiness, or other less reputable causes, pass their time in idleness, or in indolent pleasures; but I believe no state of society ever existed, in which the energy and capacity of labor were not commended and admired, or in which a taste for indolent pleasure was commended or admired by the intelligent part of the community. When we read the lives of distinguished men, in any department, we find them almost always celebrated for the amount of labor they could perform. Demosthenes, Julius Cæsar, Henry the Fourth of France, Lord Bacon, Sir Isaac Newton, Franklin, Washington, Napoleon,—different as they were in their intellectual and moral qualities,—were all renowned as hard-workers. We read how many days they could support the fatigues of a march; how early they rose, how late they watched; how many hours they spent in the field, in the cabinet, in the court; how many secretaries they kept employed; in short, how hard they worked. But who ever heard of its being said of a man in commendation, that he could sleep fifteen hours out of the twenty-four, that he could eat six meals a day, and that he never got tired of his easy-chair?

It would be curious to estimate, by any safe standard, the amount in value of the work of all kinds done in a community. This, of course, cannot be done with any great accuracy. The pursuits of men are so various, and the dif-

ferent kinds of labor performed are so different in the value of their products, that it is scarcely possible to bring the aggregate to any scale of calculation. If we would form a kind of general judgment of the value of the labor of a community, we must look about us. All the improvements, which we behold, on the face of the earth; all the buildings of every kind in town and country; all the vehicles employed on the land and water; the roads, the canals, the wharfs, the bridges; all the property of all kinds, which is accumulated throughout the world; and all that is consumed, from day to day and from hour to hour, to support those who live upon it,—all this is the product of labor; and a proportionate share is the product of the labor of each generation. —It is plain that this comprehensive view is one, that would admit of being carried out into an infinity of details, which would furnish the materials rather for a folio than a lecture. But as it is the taste of the present day, to bring every thing down to the standard of figures, I will suggest a calculation, which will enable us to judge of the value of the labor performed in the community in which we live.—Take the population of Massachusetts, for the sake of round numbers, at 600,000 souls. I presume it will not be thought extravagant to assume, that one in six performs every day a good day's work, or its equivalent. If we allow nothing for the labor of five out of six, (and this certainly will cover the cases of those too young and too old to do any work, or who can do only a part of a day's work,) and if we also allow nothing for those whose time is worth more than that of the day-laborer, we may safely assume, that the sixth person performs daily a vigorous efficient day's work of body

or mind, by hand or with tools, or partly with each, and that this day's work is worth one dollar. This will give us one hundred thousand dollars a day, as the value of the work done in the state of Massachusetts. I have no doubt that it is a good deal more,—for this would be very little more than it costs the population to support itself, and allows scarce any thing for accumulation, a good deal of which is constantly taking place. It will, however, show sufficiently the great amount of the labor done in this State, to take it as coming up, at least, to one hundred thousand dollars per day.

I have thus far laid down two propositions:—

First, that man is, by his nature, a working being; and second, that the daily value of his work, estimated merely in money, is immensely great, in any civilized community.

I have made these preliminary remarks, as an introduction to some observations, which I propose to submit, in the remainder of this lecture, on the subject of "a working men's party."—Towards the organization of such a party, steps have been taken in various parts of the country. It is probable, that a great diversity of views exists, among those who have occupied themselves upon the subject, in different places. This circumstance, and the novelty of the subject in some of its aspects, and its importance in all, have led me to think, that we might pass an hour profitably, in its contemplation.

I will observe upon it, in the first place, then, that if, as I have endeavored to show, man is by nature a working being, it would follow, that a working men's party is founded in the very principles of our nature.—Most parties may be considered as artificial in their very essence; many are local,

temporary and personal. What will the Adams, or the Jackson, or the Clay party be, a hundred years hence? What are they now, in nine-tenths of the habitable globe? Mere non-entities.—But the working men's party, however organized, is one that must subsist, in every civilized country, to the end of time. In other words, its first principles are laid in our natures.

It secondly follows, from what I have remarked above, that the working men's party concerns a vast amount of property, in which almost every man is interested; and in this respect, it differs from all controversies and parties, which end merely in speculation, or which end in the personal advancement and gratification of a few individuals.

The next question, that presents itself, is, What is the general object of a working men's party? I do not now mean, what are the immediate steps, which such a party proposes to take; but what is the main object and end, which it would secure. To this I suppose I may safely answer, that it is not to carry this or that political election; not to elevate this or that candidate for office, but to promote the prosperity and welfare of working men; that is, to secure to every man disposed to work, the greatest freedom in the choice of his pursuit, the greatest encouragement and aid in pursuing it, the greatest security in enjoying its fruits:—in other words, to make *work*, in the greatest possible degree, produce *happiness*.

The next inquiry seems to be, Who belong to the working men's party? The general answer here is obvious,—All who do the work, or are actually willing and desirous to do it, and prevented only by absolute inability, such as

sickness or natural infirmity. Let us try the correctness of this view, by seeing whom it would exclude and whom it would include.

This rule, in the first place, would exclude all bad men; that is, those who may work indeed, but who work for immoral and unlawful ends. This is a very important distinction, and, if practically applied and vigorously enforced, it would make the working men's party the purest society that ever existed since the time of the primitive Christians. It is greatly to be feared, that scarce any of the parties, that divide the community, are sufficiently jealous on this point; and for the natural reason, that it does not lie in the very nature of the parties.—Thus, at the polls, the vote of one man is as good as the vote of another. The vote of the drunkard counts one; the vote of the temperate man counts *but* one. For this reason, the mere party politician, if he can secure the vote, is apt not to be very inquisitive about the temperance of the voter. He may even prefer the intemperate to the temperate; for to persuade the temperate man to vote with him, he must give him a good reason;—the other will do it for a good drink.

But the true principles of the working men's party require, not merely that a man should work, but that he should work in an honest way and for a lawful object. The man, who makes counterfeit money, probably works harder than the honest engraver, who prepares the bills, for those authorized by law to issue them. But he would be repelled with scorn, if he presented himself as a member of the working men's party. The thief, who passes his life, and gains a wretched, precarious subsistence, by midnight trespasses on his neigh-

bor's grounds; by stealing horses from the stall, and wood from the pile; by wrenching bars and bolts at night, or picking pockets in a crowd, probably works harder, (taking uncertainty and anxiety into the calculation, and adding, as the usual consequence, four or five years in the compulsory service of the State,) than the average of men pursuing honest industry, even of the most laborious kind: but this hard work would not entitle him to be regarded as a member of the working men's party.

If it be inquired, who is to be the judge, what kind of work is not only no title, but an absolute disqualification for admission to the working men's party, on the score of dishonesty, we answer, that for all practical purposes, this must be left to the law of the land. It is true, that under cover and within the pale of the law, a man may do things morally dishonest, and such as ought to shut him out of the party. But experience has shown, that it is dangerous to institute an inquisition into the motives of individuals; and so long as a man does nothing which the law forbids,—in a country where the people make the laws,—he ought, if not otherwise disqualified, to be admitted as a member of the party.

There ought, however, perhaps, to be two exceptions to this principle; one, the case of those who pursue habitually a course of life, which, though contrary to law, is not usually punished by the law, such as persons habitually intemperate. It is plain, that these men ought not to be allowed to act with the party, because they would always be liable, by a very slight temptation, to be made to act in a manner hostile to its interests; and because they are habitually

in a state of incapacity to do any intelligent and rational act.

The other exception ought to be of men who take advantage of the law to subserve their own selfish and malignant passions. This is done in various ways, but I will allude to but one. The law puts it in the power of the creditor, not merely to seize the property of the debtor, in payment of the debt, but to consider every case of inability as a case of fraudulent concealment, and to punish it, as such, by imprisonment. This is often done in a way to inflict the greatest possible pain, and in cases in which not only no advantage but additional cost accrues to the creditor. A man who thus takes the advantage of the law, to wreak upon others his malignant passions, ought to be excluded, not merely from the working men's party, but from the pale of civilized society.

The next question regards idlers. If we exclude from the working men's party all dishonest and immoral workers, what are we to say to the case of the idlers?—In general terms, the answer to this question is plain; they too must be excluded. With what pretence of reason can an idler ask to be admitted into the association of working men, unless he is willing to qualify himself by going to work? and then he ceases to be an idler. In fact, the man who idles away his time, acts against the law of his nature, as a working being. It must be observed, however, that there are few cases where a man is *merely* an idler. In almost every case, he must be something worse,—such as a spendthrift, a gamester, or an intemperate person; a bad son, a bad husband, and a bad father. If there are any persons de-

pendent on him for support; if he idles away the time which he ought to devote to maintaining his wife, or his children, or his aged parents, he then becomes a robber; a man that steals the bread out of the mouths of his own family, and the clothes off their backs; and he is as much more criminal than the common highway robber, who takes the stranger's purse on the turnpike, as the ties of duty to our parents and children are beyond those of common justice between man and man. But I suppose it would not require much argument to show, that the person, who leaves to want those whom he ought to support, even if he does not pass his idle hours in any criminal pursuit, has no right to call himself a working man.

There is a third class of men, whose case deserves consideration, and who are commonly called busy-bodies.—They are as different from real working men, as light is from darkness. They cannot be called idlers, for they are never at rest; nor yet workers, for they pursue no honest, creditable employment. So long as they are merely busy-bodies, and are prompted in their officious, fluttering, unproductive activity, by no bad motive and no malignant passion, they cannot, perhaps, be excluded from the party, though they have really no claim to be admitted into it. But here, too, the case of a *mere* busy-body scarce ever occurs. This character is almost always something more; a dangerous gossip, a tattling mischief-maker, a propagator, too frequently an inventor of slander. He repeats at one fireside, with additions, what he heard at another, under the implied obligation of confidence; he is commonly in the front rank of all uneasy and inconsiderate movements, safely

entrenched behind his neighbor, whom he pushes into trouble; and he is very fond of writing anonymous libels in the newspapers, on men of whom he knows nothing. Such men—and there are too many of them—ought to be excluded from the party.

Shutting out, then, all who work dishonestly, and all who do not work at all, and admitting the busy-bodies with great caution, the working men's party comprehends all those by whom the work of the community is really done;—all those who, by any kind of honest industry, employ the talent which their Creator has given them. All these form one great party, one comprehensive society, and this by the very law of our nature. Man is not only, as I observed in the beginning, a working being; but he is a being formed to work in society; and if the matter be carefully analysed, it will be found, that civilization, that is, the bringing men out of a savage into a cultivated state, consists in multiplying the number of pursuits and occupations: so that the most perfect society is one where the largest number of persons are prosperously employed, in the greatest variety of ways. In such a society, men help each other, instead of standing in each other's way. The farther this division of labor is carried, the more persons must unite, harmoniously, to effect the common ends. The larger the number, on which each depends, the larger the number to which each is useful.

This union of different kinds of workmen in one harmonious society seems to be laid in the very structure and organization of man. Man is a being consisting of a body and a soul. These words are *soon* uttered, and they are so *often* uttered, that the mighty truth, which is embraced

in them, scarce ever engages our attention.—But man is composed of body and soul. What is body? It is material substance; it is clay, dust, ashes. Look at it, as you tread it unorganized beneath your feet; contemplate it, when, after having been organized and animated, it is, by a process of corruption, returning to its original state. Matter, in its appearance to us, is an unorganized, inanimate, cold, dull, and barren thing. What it is in its essence, no one but the Being who created it knows. The human mind can conceive of it only as the absolute negation of qualities. And we say, that the body of man is formed of the clay or dust; because these substances seem to us to make the nearest approach to the total privation of all the properties of intellect. Such is the *body* of man.—What is his *soul*?—Its essence is as little known to us as that of body; but its qualities are angelic, divine. It is soul, which thinks, reasons, invents, remembers, hopes, and loves. It is the soul which lives; for when the soul departs from the body, all its vital powers cease; and it is dead;—and what is the body then?

Now the fact, to which I wish to call your attention, is, that these two elements, one of which is akin to the poorest dust on which we tread, and the other of which is of the nature of angelic and even of divine intelligence, are, in every human being, without exception, brought into a most intimate and perfect union. We can conceive, that it might have been different. God could have created matter by itself and mind by itself. We believe in the existence of incorporeal beings of a nature higher than man; and we behold beneath us in brutes, plants, and stones, various orders of

material nature, rising, one above another, in organization; but none of them (as we suppose) possessing mind.—We can imagine a world so constituted, that all the intellect would have been by itself, pure and disembodied; and all the material substance by itself unmixed with mind; and acted upon by mind, as inferior beings are supposed to be acted upon by angels. But in constituting our race, it pleased the Creator to bring the two elements into the closest union; to take the body from the dust; the soul from the highest heaven; and mould them into one.

The consequence is, that the humblest laborer, who works with his hands, possesses within him a soul, endowed with precisely the same faculties as those which in Franklin, in Newton, or Shakspeare, have been the light and the wonder of the world; and on the other hand, the most gifted and ethereal genius, whose mind has fathomed the depths of the heavens and comprehended the whole circle of truth, is enclosed in a body, subject to the same passions, infirmities, and wants, as the man whose life knows no alternation but labor and rest, appetite and indulgence.

Did it stop here, it would be merely an astonishing fact in the constitution of our natures;—but it does not stop here. In consequence of the union of the two principles in the human frame, every act, that a man performs, requires the agency both of body and mind. His mind cannot see, but through the optic eye-glass; nor hear till the drum of his ear is affected by the vibrations of the air. If he would speak, he puts in action the complex machinery of the vocal organs; if he writes, he employs the muscular system of the hands; nor can he even perform the operations of

pure thought, except in a healthy state of the body. A fit of the tooth-ache, proceeding from the irritation of a nerve about as big as a cambric-thread, is enough to drive an understanding, capable of instructing the world, to the verge of insanity. On the other hand, there is no operation of manual labor so simple, so mechanical, which does not require the exercise of perception, reflection, memory, and judgment; the same intellectual powers, by which the highest truths of science have been discovered and illustrated.

The degree to which any particular action (or series of actions united into a pursuit) shall exercise the intellectual powers, on the one hand, or the mechanical powers on the other, of course, depends on the nature of that action. The slave whose life from childhood to the grave is passed in the field; the New Zealander who goes to war, when he is hungry, devours his prisoners, and leads a life of cannibal debauch till he has consumed them all, and then goes to war again; the Greenlander, who warms himself with the fragments of wrecks and drift-wood thrown upon the glaciers, and feeds himself with blubber; seem all to lead lives requiring but little intellectual action; and yet, as I have remarked, a careful reflection would show that there is not one, even of them, who does not, every moment of his life, call into exercise, though in an humble degree, all the powers of the mind. In like manner, the philosopher who shuts himself up in his cell, and leads a contemplative existence, among books or instruments of science, seems to have no occasion to employ, in their ordinary exercise, many of the capacities of his nature for physical action;—although he

also, as I have observed, cannot act, or even think, but with the aid of his body.

This is unquestionably true. The same Creator who made man a mixed being, composed of body and soul, having designed him for such a world as that in which we live, has so constituted the world, and man who inhabits it, as to afford scope for great variety of occupations, pursuits, and conditions, arising from the tastes, characters, habits, virtues, and even vices, of men and communities. For the same reason, that—though all men are alike composed of body and soul, yet no two men probably are exactly the same in respect to either;—*so* provision has been made, by the Author of our being, for an infinity of pursuits and employments, calling out, in degrees as various, the peculiar powers of both principles.

But I have already endeavored to show, that there is no pursuit and no action that does not require the united operation of both; and this of itself is a broad natural foundation for the union into one interest of all, in the same community, who are employed in honest work of any kind; viz. that, however various their occupations, they are all working with the same instruments; the organs of the body and the powers of the mind.

But we may go a step farther, to remark the beautiful process, by which Providence has so interlaced and wrought up together the pursuits, interests, and wants of our nature, that the philosopher, whose home seems less on earth than among the stars, requires, for the prosecution of his studies, the aid of numerous artificers in various branches of mechanical industry; and, in return, furnishes the most important

facilities to the humblest branches of manual labor. Let us take, as a single instance, that of astronomical science. It may be safely said, that the wonderful discoveries of modern astronomy, and the philosophical system depending upon them, could not have existed, but for the *telescope*. The want of the telescope kept astronomical science in its infancy among the ancients. Although Pythagoras, one of the earliest Greek philosophers, by a fortunate exercise of sagacity, conceived the elements of the Copernican system, yet we find no general and practical improvement resulting from it. It was only from the period of the discoveries, made by the telescope, that the science advanced, with sure and rapid progress. Now the astronomer does not make telescopes. I presume it would be impossible for a person, who employed in the abstract study of astronomical science time enough to comprehend its profound investigations, to learn and practise the trade of making glass. It is mentioned, as a remarkable versatility of talent in one or two eminent observers, that they have superintended the cutting and polishing of the glasses of their own telescopes. But I presume if there never had been a telescope, till some scientific astronomer had learned to mix, melt, and mould glass, such a thing would never have been heard of. It is not less true, that those employed in making the glass could not, in the nature of things, be expected to acquire the scientific knowledge, requisite for carrying on those arduous calculations, applied to bring into a system the discoveries made by the magnifying power of the telescope. I might extend the same remark to the other materials, of which a telescope consists. It cannot be used to any purpose of

nice observation, without being very carefully mounted, on a frame of strong metal; which demands the united labors of the mathematical instrument-maker and the brass-founder. Here then, in taking but one single step out of the philosopher's observatory, we find he needs an instrument, to be produced by the united labors of the mathematical instrument-maker, the brass-founder, the glass-polisher, and the maker of glass, four trades.* He must also have an astronomical clock, and it would be easy to count up half a dozen trades, which directly or indirectly are connected in making a clock. But let us go back to the *object-glass* of the telescope. A glass factory requires a building and furnaces. The man who makes the glass, does not make the building. But the stone and brick mason, the carpenter, and the blacksmith must furnish the greater part of the labor and skill, required to construct the building. When it is built, a large quantity of fuel, wood and wood-coal, or mineral coal of various kinds, or all together, must be provided; and then the materials of which the glass is made, and with which it is colored, some of which are furnished by commerce from different and distant regions, and must be brought in ships across the sea. We cannot take up any one of *these* trades, without immediately finding that it connects itself with numerous others. Take, for instance, the mason who builds the furnace. He does not make his own bricks, nor burn his own lime; in common cases, the bricks come from one place, the lime from another, the sand from another. The brick-maker does not cut down his own wood.

* The allusion is here to the simplest form of a telescope. The illustration would be stronger in the case of a reflector.

It is carted or brought in boats to his yard. The man who carts it does not make his own wagon; nor does the person who brings it in boats, build his own boat. The man who makes the wagon, does not make its tire. The blacksmith, who makes the tire, does not smelt the ore; and the forge-man who smelts the ore, does not build his own furnace, (and there we get back to the point whence we started,) nor dig his own mine. The man who digs the mine, does not make the pick-axe with which he digs it; nor the pump with which he keeps out the water. The man who makes the pump, did not discover the principle of atmospheric pressure, which led to pump-making: that was done by a mathematician at Florence, experimenting in his chamber, on a glass tube. And here we come back again to our glass; and to an instance of the close connexion of scientific research with practical art. It is plain, that this enumeration might be pursued till every art and every science were shown to run into every other. No one can doubt this, who will go over the subject in his own mind, beginning with any one of the processes of mining and working metals, of ship-building, and navigation, and the other branches of art and industry, pursued in civilized communities.

If then, on the one hand, the astronomer depends for his telescope on the ultimate product of so many arts; in return, his observations are the basis of an astronomical system and of calculations of the movements of the heavenly bodies, which furnish the mariner with his best guide across the ocean. The prudent ship-master would no more think of sailing for India, without his Bowditch's *Practical Navigator*,

than he would without his compass; and this Navigator contains tables, drawn from the highest walks of astronomical science. Every first mate of a vessel, who works a lunar observation, to ascertain the ship's longitude, employs tables, in which the most wonderful discoveries and calculations of La Place, and Newton, and Bowditch, are interwoven.

I mention this as but one of the cases, in which astronomical science promotes the service and convenience of common life; and perhaps, when we consider the degree to which the modern extension of navigation connects itself with industry in all its branches, this may be thought sufficient. I will only add, that the cheap convenience of an almanac, which enters into the comforts of every fireside in the country, could not be enjoyed, but for the labors and studies of the profoundest philosophers. Not that great learning or talent is now required to execute the astronomical calculations of an almanac, although no inconsiderable share of each is needed for this purpose; but because, even to perform these calculations requires the aid of tables, which have been gradually formed on the basis of the profoundest investigations of the long line of philosophers, who have devoted themselves to this branch of science. For, as we observed on the mechanical side of the illustration, it was not one trade alone, which was required to furnish the philosopher with his instrument, but a great variety; so, on the other hand, it is not the philosopher in one department, who creates a science out of nothing. The observing astronomer furnishes materials to the calculating astronomer, and the calculator derives methods from the pure mathematician; and

a long succession of each for ages must unite their labors, in a great result. Without the geometry of the Greeks, and the algebra of the Arabs, the infinitesimal analysis of Newton and Leibnitz would never have been invented.

Examples and illustrations equally instructive might be found in every other branch of industry. The man, who will go into a cotton-mill, and contemplate it from the great water-wheel, that gives the first movement, (and still more from the steam-engine, should that be the moving power,) who will observe the parts of the machinery, and the various processes of the fabric, till he reaches the hydraulic press, with which it is made into a bale, and the canal or rail-road by which it is sent to market, may find every branch of trade and every department of science literally crossed, intertwined, interwoven with every other, like the woof and the warp of the article manufactured. Not a little of the spinning machinery is constructed on principles drawn from the demonstrations of transcendental mathematics; and the processes of bleaching and dying, now practised, are the results of the most profound researches of modern chemistry.—And if this does not satisfy the inquirer, let him trace the cotton to the plantation, where it grew, in Georgia or Alabama; the indigo to Bengal; the oil to the olive-gardens of Italy, or the fishing-grounds of the Pacific Ocean; let him consider Whitney's cotton-gin; Whittemore's carding-machine; the power-loom; and the spinning apparatus; and all the arts, trades, and sciences, directly or indirectly connected with these; and I believe he will soon agree, that one might start from a yard of coarse printed cotton, which costs ten cents, and prove out

of it, as out of a text, that every art and science under heaven had been concerned in its fabric.

I ought here to allude, also, to some of those pursuits which require the ability to exercise, at the same time, on the part of the same individual, the faculties, both of the intellectual and physical nature,—or which unite very high and low degrees of mental power. I have no doubt, that the talent for drawing and painting, possessed by some men to such an admirable degree, depends partly on a peculiar organic structure of the eye, and of the muscles of the hand, which gives them their more delicate perceptions of color and their greater skill in delineation. These, no doubt, are possessed by many individuals, who want the intellectual talent,—the poetic fire,—required for a great painter. On the other hand, I can conceive of a man's possessing the invention and imagination of a painter, without the eye and the hand required to embody on the canvass the ideas and images in his mind. When the two unite, they make a Raphael or a Titian; a Martin or an Allston. An accomplished statuary, such as Canova or Chantrey, must, on the one hand, possess a soul filled with all grand and lovely images, and have a living conception of ideal beauty; and on the other hand, he must be a good stone-cutter, and able to take a hammer and a chisel in his hand, and go to work on a block of marble, and chip it down to the lip of Apollo or the eyelid of Venus.—The architect must be practically acquainted with all the materials of building, wood, brick, mortar, and stone; he must have the courage and skill to plant his moles against the heaving ocean, and to hang his ponderous domes and gigantic arches in the air; while he

must have taste to combine the rough and scattered blocks of the quarry into beautiful and majestic structures; and discern clearly in his mind's eye, before a sledge-hammer has been lifted, the elevation and proportions of the temple. The poet must know, with a schoolmaster's precision, the weight of every word, and what vowel follows most smoothly, on what consonant; at the same time, that his soul must be stored with images, feelings, and thoughts, beyond the power of the boldest and most glowing language, to do more than faintly shadow out. The surgeon must, at once, have a mind naturally gifted and diligently trained, to penetrate the dark recesses of organic life; and a nerve and tact, which will enable him to guide his knife among veins and arteries, out of sight, in the living body of an agonizing, shrieking fellow creature, or to take a lancet in his left hand, and cut into the apple of the eye. The lawyer must be able to reason from the noblest principles of human duty and the most generous feelings of human nature; he must fully comprehend the mighty maze of the social relations; he must carry about with him a stock of learning almost boundless; he must be a sort of god to men and communities, who look up to him, in the hour of the dearest peril of their lives and fortunes; and he must at the same time be conversant with a tissue of the most senseless fictions and arbitrary technology, that ever disgraced a liberal science. The merchant must be able to look, at the same moment, at the markets and exchanges of distant countries and other hemispheres, and combine considerations of the political condition, the natural wants, the tastes and habits of different parts of the world; and he must be expert at figures

—understand book-keeping by double entry,—and know as well how to take care of a quarter chest of tea as a cargo of specie. The general-in-chief must be capable of calculating for a twelvemonth in advance the result of a contest, in which all the power, resource, and spirit of two great empires enter and struggle, on land and by sea; and he must have an eye, that can tell at a glance, and on the responsibility of his life, how the stone walls, and trenched meadows, the barns, and the woods, and the cross-roads of a neighborhood, will favor or resist the motions of a hundred thousand men, scattered over a space of five miles, in the fury of the advance, the storm of battle, the agony of flight, covered with smoke, dust, and blood.*

It was my intention to subject the art of printing to an analysis of the trades, arts and sciences connected with it; but I have not time to do it full justice, and the bare general idea need not be repeated. I will only say that, beginning with the invention, which bears in popular tradition the name of Cadmus, I mean the invention of alphabetical signs to express sounds, and proceeding to the discovery of convenient materials for writing, and the idea of written discourse; thence to the preparation of manuscript books; and thence to the fabric, on a large scale, of linen and cotton paper, the invention of moveable types, and the printing press, the art of engraving on metal, of stereotype printing, and of the power press,—we have a series of discoveries, branching out into others in every department of human pursuit; connecting the highest philosophical principles with

* This paragraph is taken, with some alterations, from an Essay, published by the author some years ago in a Periodical Journal.

the results of mere manual labor, and producing, in the end, that system of diffusing and multiplying the expression of thought, which is, perhaps, the glory of our human nature. Pliny said, that the Egyptian reed was the support on which the immortal fame of man rested. He referred to its use in the manufacture of paper. We may with greater justice say as much of the manufacture of paper from rags, and of the printing press, neither of which was known to Pliny.—But with all the splendor of modern discoveries and improvements in science and art, I cannot but think that he, who, in the morning of the world, first conceived the idea of representing sounds by visible signs, took the most important step in the march of improvement. This sublime conception was struck out in the infancy of mankind. The name of its author, his native country, and the time when he lived, are known only by very uncertain tradition; but though all the intelligence of ancient and modern times, and in the most improved countries, has been concentred into a focus, burning and blazing upon this one spot, it has never been able to reduce it to any simpler elements, nor to improve, in the slightest degree, upon the original suggestion of Cadmus.

In what I have thus far submitted to you, you will probably have remarked, that I have illustrated chiefly the connexion with each other of the various branches of science and art; of the intellectual and physical principles. I have not distinctly shown the connexion of the moral principle, in all its great branches, with both. This subject would well form the matter of a separate essay. But its elementary ideas are few and plain. The arts and sciences, whose connexion we have pointed out, it is plain, require for their

cultivation a civilized state of society. They cannot thrive in a community which is not in a state of regular political organization, under an orderly system of government, uniform administration of laws, and a general observance of the dictates of public and social morality. Farther, such a community cannot exist without institutions of various kinds for elementary, professional, and moral education; and connected with these, are required the services of a large class of individuals, employed in various ways, in the business of instruction; from the meritorious schoolmaster, who teaches the little child its A, B, C, to the moralist, who lays down the great principles of social duty for men and nations, and the minister of divine truth, who inculcates those sanctions, by which God himself enforces the laws of reason. There must also be a class of men competent by their ability, education, and experience, to engage in the duty of making and administering the law, for in a lawless society it is impossible that any improvement should be permanent. There must be another class competent to afford relief to the sick, and thus protect our frail natures from the power of the numerous foes that assail them.

It needs no words to show, that all these pursuits are in reality connected with the ordinary work of society, as directly as the mechanical trades, by which it is carried on.—For instance, nothing would so seriously impair the prosperity of a community, as an unsound and uncertain administration of justice. This is the last and most fatal symptom of decline in a state. A community can bear a very considerable degree of political despotism, if justice is duly administered between man and man. But where a man has

no security, that the law will protect him in the enjoyment of his property; where he cannot promise himself a righteous judgment in the event of a controversy with his neighbor; where he is not sure, when he lies down at night, that his slumbers are safe, there he loses the great motives to industry and probity; credit is shaken; enterprise disheartened, and the State declines.—The profession, therefore, which is devoted to the administration of justice, renders a service to every citizen of the community, as important as to those whose immediate affairs require the aid of counsel.

In a very improved and civilized community, there are also numerous individuals, who, without being employed in any of the common branches of industry or of professional pursuit, connect themselves, nevertheless, with the prosperity and happiness of the public, and fill a useful and honorable place in its service. Take, for instance, a man like Sir Walter Scott, who probably never did a day's work, in his life, in the ordinary acceptation of the term, and who has for some years retired from the subordinate station he filled in the profession of the law, as sheriff of the county and clerk of the Court. He has written and published at least two hundred volumes of wide circulation. What a vast amount of the industry of the community is thereby put in motion!—The booksellers, printers, paper-makers, press-makers, type-makers, book-binders, leather-dressers, ink-makers, and various other artisans required to print, publish, and circulate the hundreds and thousands of volumes, of the different works, which he has written, must be almost numberless. I have not the least doubt, that, since the series of his publications began, if all whose industry,—directly

or remotely,—has been concerned in them, not only in Great Britain, but in America, and on the Continent of Europe, could be brought together and stationed side by side, as the inhabitants of the same place, they would form *a very considerable town.* Such a person may fairly be ranked as a working man.

And yet I take this to be the least of Sir Walter Scott's deserts. I have said nothing of the service rendered to every class, and to every individual in every class, by the writer, who beguiles of their tediousness the dull hours of life; who animates the principle of goodness within us, by glowing pictures of struggling virtue; who furnishes our young men and women with books, which they may read with interest, and not have their morals poisoned as they read them. Our habits, our principles, our characters,—whatever may be our pursuit in life,—depend very much on the nature of our youthful pleasures, and on the mode in which we learn to pass our leisure hours. And he who, with the blessing of Providence, has been able, by his mental efforts, to present virtue in her strong attractions, and vice in her native deformity, to the rising generation, has rendered a service to the public, greater even than his, who invented the steam-engine, or the mariner's compass.

I have thus endeavored to show, in a plain manner, that there is a close and cordial union between the various pursuits and occupations, which receive the attention of men in a civilized community:—That they are links of the same chain, every one of which is essential to its strength.

It will follow, as a necessary consequence; as the dictate of reason and as the law of nature;—that every man in so-

ciety, whatever his pursuit, who devotes himself to it, with an honest purpose, and in the fulfilment of the social duty which Providence devolves upon him, is entitled to the good fellowship of each and every other member of the community;—that all are the parts of one whole; and that between those parts, as there is but one interest, so there should be but one feeling.

Before I close this lecture, permit me to dwell for a short time on the principle, which I have had occasion to advance above, that the immortal element in our nature—the reasoning soul—is the inheritance of all our race. As it is this which makes man superior to the beasts that perish; so it is this, which, in its moral and intellectual endowments, is the sole foundation for the only distinctions between man and man, which have any real value. This consideration shows the value of institutions for education and for the diffusion of knowledge. It was no magic, no miracle, which made Newton, and Franklin, and Fulton. It was the patient, judicious, long-continued cultivation of powers of the understanding, eminent, no doubt, in degree, but not differing in kind, from those which are possessed by every individual in this assembly.

Let every one then reflect, especially every person not yet passed the forming period of his life, that he carries about in his frame as in a casket, the most glorious thing, which, this side heaven, God has been pleased to create, an intelligent spirit. To describe its nature, to enumerate its faculties, to set forth what it has done, to estimate what it can do, would require the labor of a life devoted to the history of Man. It would be vain, on this occasion and in these

limits, to attempt it. But let any man compare his own nature with that of a plant, of a brute beast, of an idiot, of a savage; and then consider that it is in mind alone, and the degree to which he improves it, that he differs essentially from any of them.

And let no one think he wants opportunity, encouragement or means.—I would not undervalue these, any or all of them, but compared with what the man does for himself, they are of little account. Industry, temperance, and perseverance are worth more than all the patrons, that ever lived in all the Augustan ages. It is these, that create patronage and opportunity. The cases of our Franklin and Fulton are too familiar to bear repetition. Consider that of Sir Humphrey Davy, who died last year, and who was in many departments of science, the first philosopher of the age.*—He was born at Penzance in Cornwall, one of the darkest corners of England; his father was a carver of wooden images for signs, and figure-heads, and chimney-pieces. He himself was apprenticed to an apothecary, and made his first experiments in chemistry with his master's phials and gallipots, aided by an old syringe, which had been given him by the surgeon of a French vessel, wrecked on the Land's End. From the shop of the apothecary, he was transferred to the office of a surgeon; and never appears to have had any other education, than that of a Cornish school, in his boyhood. Such was the beginning of the career of the man, who, at the age of twenty-two, was selected, by our own countryman, Count Rumford,

* The sketch of Sir Humphrey Davy which follows, to the end of the lecture, is abridged from the article in the Annual Biography for 1830.

(himself a self-taught benefactor of mankind,) to fill the chair of Chemistry at the Royal Institution, in London, such was the origin and education of the man, who discovered the metallic basis of the alkalis and the earths; invented the safety-lamp; and placed himself, in a few years, in the chair of the Royal Society of London, and at the head of the chemists of Europe. Sir Humphrey Davy's most brilliant discoveries were effected by his skilful application of the Galvanic Electricity, a principle, whose existence had been detected, a few years before, by an Italian philosopher, from noticing the contractions of a frog's limb suspended on an iron hook, a fact which shows how near us, in every direction, the most curious facts lie scattered by nature. With an apparatus, contrived by himself to collect and condense this powerful agent, Sir Humphrey succeeded in decomposing the earths and the alkalis; and in extracting from common potash, the metal (before unknown) of which it consists;—possessing at 70° of the thermometer the lustre and general appearance of mercury, at 50°, the appearance of polished silver and the softness of wax; so light that it swims in water; and so inflammable that it takes fire, when thrown on ice.

These are perhaps but brilliant novelties; though connected, no doubt, in the great chain of cause and effect, with principles of art and science, conducive to the service of man. But the invention of the safety-lamp, which enables the miner to walk unharmed through an atmosphere of explosive gas, and has already saved the lives of hundreds of human beings, is a title to glory and the gratitude of his

fellow men, which the most renowned destroyer of his race might envy.

The counsels of such a man, in his retirement and meditation, are worth listening to. I am sure you will think I bring this lecture to the best conclusion, by repeating a sentence from one of his moral works:—

"I envy," says he, "no quality of the mind or intellect in others; not genius, power, wit or fancy; but if I could choose what would be most delightful, and I believe most useful to me, I should prefer A FIRM RELIGIOUS BELIEF to every other blessing."

OBJECTS,

ADVANTAGES, AND PLEASURES

OF

SCIENCE.

INTRODUCTION. I. *Mathematical Science.* II. *Difference between Mathematical and Physical Truths.* III. *Natural or Experimental Science.* IV. *Application of Natural Science to the Animal and Vegetable World.* V. *Advantages and Pleasures of Science.*

IN order fully to understand the advantages and the pleasures which are derived from an acquaintance with any science, it is necessary to become acquainted with that science, and it would therefore be impossible to convey a complete knowledge of the benefits conferred by a study of the various sciences which have hitherto been chiefly cultivated by philosophers, without teaching all the branches of them. But a very distinct idea may be given of those benefits, by explaining the nature and objects of the different sciences; it may be shown by examples how much use and gratification there is in learning a part of any one branch of knowledge; and it may thus be inferred, how great reason there is to learn the whole.

It may be easily demonstrated, that there is an advantage in learning, both for the usefulness and the pleasure of it. There is something positively agreeable to all men, to all at least whose nature is not most grovelling and base, in gaining knowledge for its own sake. When you see any thing for the first time, you at once derive some gratification from the sight being new; your attention is awakened, and you desire to know more about it. If it is a piece of workmanship, as an instrument, a machine of any kind, you wish to know how it is made; how it works; and what use it is of. If it is an animal, you desire to know where it comes from; how it lives; what are its dispositions, and, generally, its nature and habits. This desire is felt, too, without at all considering that the machine or the animal may ever be of the least use to yourself practically; for, in all probability, you may never see them again. But you feel a curiosity to learn all about them, because they are new and unknown to you. You accordingly make inquiries; you feel a gratification in getting answers to your questions, that is, in receiving information, and in knowing more,—in being better informed than you were before. If you ever happen again to see the same instrument or animal, you find it agreeable to recollect having seen it before, and to think that you know something about it. If you see another instrument or animal, in some respects like, but differing in other particulars, you find it pleasing to compare them together, and to note in what they agree, and in what they differ. Now, all this kind of gratification is of a pure and disinterested nature, and has no reference to any of the common purposes of life; yet it is a pleasure—an enjoyment. You are nothing the richer for it; you do not gratify your palate or any other bodily appetite; and yet it is so pleasing that you would give something out of your pocket to obtain it, and would forego some bodily enjoyment for its sake. The pleasure derived from science is exactly of the like nature, or, rather, it is the very same. For what has just been referred to is in fact Science, which in its most comprehensive sense only means *Knowledge*, and in its ordinary

sense means ***Knowledge reduced to a system;*** that is, arranged in a regular order so as to be conveniently taught, easily remembered, and readily applied.

The practical uses of any science or branch of knowledge are undoubtedly of the highest importance; and there is hardly any man who may not gain some positive advantage in his worldly wealth and comforts, by increasing his stock of information. But there is also a pleasure in seeing the uses to which knowledge may be applied, wholly independent of the share we ourselves may have in those practical benefits. It is pleasing to examine the nature of a new instrument, or the habits of an unknown animal, without considering whether they may be of use to ourselves or to any body. It is another gratification to extend our inquiries, and find that the instrument or animal is useful to man, even although we have no chance ourselves of ever benefitting by the information; as, to find that the natives of some distant country employ the animal in travelling;—nay, though we have no desire of benefitting by the knowledge; as, for example, to find that the instrument is useful in performing some dangerous surgical operation. The mere gratification of curiosity; the knowing more to-day than we knew yesterday; the understanding what before seemed obscure and puzzling; the contemplation of general truths, and the comparing together of different things,—is an agreeable occupation of the mind; and, beside the present enjoyment, elevates the faculties above low pursuits, purifies and refines the passions, and helps our reason to assuage their violence.

It is very true, that the fundamental lessons of philosophy may to many at first sight wear a forbidding aspect, because to comprehend them requires an effort of the mind somewhat, though certainly not much, greater than is wanted for understanding more ordinary matters; and the most important branches of philosophy, those which are of the most general application, are for that very reason the less easily followed, and the less entertaining when apprehended, presenting as they do few particulars and individual objects to the mind. In discoursing of them, moreover, no

figures will be at present used to assist the imagination; the appeal is made to reason, without help from the senses. But be not therefore prejudiced against the doctrine, that the pleasure of learning the truths which philosophy unfolds is truly above all price. Lend but a patient attention to the principles explained, and giving us credit for stating nothing which has not some practical use belonging to it, or some important doctrine connected with it, you will soon perceive the value of the lessons you are learning, and begin to interest yourselves in comprehending and recollecting them; you will find that you have actually learnt something of science, while merely engaged in seeing what its end and purpose is; you will be enabled to calculate for yourselves, how far it is worth the trouble of acquiring, by examining samples of it; you will, as it were, taste a little to try whether or not you relish it, and ought to seek after more; you will enable yourselves to go on, and enlarge your stock of it; and after having first mastered a very little, you will proceed so far as to look back with wonder at the distance you have reached beyond your earliest acquirements.

The Sciences may be divided into three great classes: those which relate to *Number and Quantity*, those which relate to *Matter*, and those which relate to *Mind*. The first are called the *Mathematics*, and teach the properties of numbers and of figures; the second are called *Natural Philosophy*, and teach the properties of the various bodies which we are acquainted with by means of our senses; the third are called *Intellectual* or *Moral Philosophy*, and teach the nature of the mind, of the existence of which we have the most perfect evidence in our own reflections; or, in other words, the moral nature of man, both as an individual and as a member of society. Connected with all the sciences, and subservient to them, though not one of their number, is *History*, or the record of facts relating to all kinds of knowledge.

I. The two great branches of the *Mathematics*, or the two mathematical sciences, are *Arithmetic*, the science of

number, from the Greek word signifying *number*, and *Geometry*, the science of figure, from the Greek words signifying *measure of the earth*,—land measuring having first turned men's attention to it.

When I say that 2 and 2 make 4, I state an arithmetical proposition, very simple indeed, but connected with many others of a more difficult and complicated kind. Thus, it is another proposition, somewhat less simple, but still very obvious, that 5 multiplied by 10, and divided by 2 is equal to, or makes the same number with, 100 divided by 4—both results being equal to 25. So, to find how many farthings there are in £1000, and how many minutes in a year, are questions of arithmetic which we learn to work by being taught the principles of the science one after another, or, as they are commonly called, the *rules* of addition, subtraction, multiplication, and division. Arithmetic may be said to be the most simple, though among the most useful of the sciences; but it teaches only the properties of particular and known numbers, and it only enables us to add, subtract, multiply, and divide those numbers. But suppose we wish to add, subtract, multiply, or divide numbers which we have not yet ascertained, and in all respects to deal with them as if they were known, for the purpose of arriving at certain conclusions respecting them, and among other things, of discovering what they are; or, suppose we would examine properties belonging to all numbers; this must be performed by a peculiar kind of arithmetic, called *universal* arithmetic, or *Algebra*.* The common arithmetic, you will presently perceive, carries the seeds of this most important science in its bosom. Thus, suppose we inquire what is the number which multiplied by 5 makes 10? this is found if we divide 10 by 5—it is 2; but suppose that, before finding this number 2, and before knowing what it is, we would add it, whatever it may turn out, to some other number; this can only be done by putting some mark, such as a letter of the alphabet, to stand

* Algebra, from the Arabic words signifying the *reduction of fractions*; the Arabs having brought the knowledge of it into Europe.

for the unknown number, and adding that letter as if it were a known number. Thus, suppose we want to find two numbers, which, added together, make 9, and multiplied by one another make 20. There are many, which added together, make 9; as 1 and 8; 2 and 7; 3 and 6; and so on. We have, therefore, occasion to use the second condition, that multiplied by one another they should make 20, and to work upon this condition before we have discovered the particular numbers. We must, therefore, suppose the numbers to be found, and put letters for them, and by reasoning upon those letters, according to both the two conditions of adding and multiplying, we find what they must each of them be in numbers, in order to fulfil or answer the conditions. Algebra teaches the rules for conducting this reasoning, and obtaining this result successfully; and by means of it we are enabled to find out numbers which are unknown, and of which we only know that they stand in certain relations to known numbers, or to one another. The instance now taken is an easy one; and you could, by considering the question a little, answer it readily enough; that is, by trying different numbers, and seeing which suited the conditions; for you plainly see that 5 and 4 are the two numbers sought; but you see this by no certain or general rule applicable to all cases, and therefore you never could work more difficult questions in the same way; and even questions of a moderate degree of difficulty would take an endless number of trials or guesses to answer. Thus, if a ship, say a smuggler, is sailing at the rate of 8 miles an hour, and a revenue cutter, sailing at the rate of 10 miles an hour, descries her 18 miles off, and gives chase, and you want to know in what time the smuggler will be overtaken, and how many miles she will have sailed before being overtaken; this, which is one of the simplest questions in algebra, would take you a long time, almost as long as the chase, to come at by mere trial and guessing (the chase would be 9 hours, and the smuggler would sail 72 miles:) and questions only a little more difficult than this, never could be answered by any number of guesses; yet questions infinitely more difficult can easily

be solved by the rules of algebra. In like manner, by arithmetic you can tell the properties of particular numbers; as, for instance, that the number 348 is divided by 3 exactly, so as to leave nothing over: but algebra teaches us that it is only one of an infinite variety of numbers, all divisible by 3, and any one of which you can tell the moment you see it; for they all have the remarkable property, that if you add together the figures they consist of, the sum total is divisible by 3. You can easily perceive this in any one case, as in the number mentioned, for 3 added to 4 and that to 8 make 15, which is plainly divisible by 3; and if you divide 348 by 3, you find the quotient to be 116, and nothing over. But this does not at all prove that any other number, the sum of whose figures is divisible by 3, will itself also be found divisible by 3, as 741; for you must actually perform the division here, and in every other case, before you can know that it leaves nothing over. Algebra, on the contrary, both enables you to discover such general properties, and to prove them in all their generality.*

By means of this science, and its various applications, the most extraordinary calculations may be performed. We shall give, as an example, the method of *Logarithms*, which proceeds upon this principle. Take a set of numbers going on by equal differences; that is to say, the third being as much greater than the second, as the second is greater than the first; thus, 1, 2, 3, 4, 5, 6, and so on, in which the common difference is 1; then take another set of numbers, such that each is equal to twice or three times the one before it, or any number of times the one before it; thus, 2, 4, 8, 16, 32, 64, 128; write this second set

* Another class of numbers divisible by 3 is discovered in like manner by algebra. Every number of 3 places, the figures (or digits) composing which are in arithmetical progression, (or rise above each other by equal differences) is divisible by 3: as, 123, 789, 357, 159, and so on. The same is true of numbers of any amount of places, provided they are composed of 3, 6, 9, &c. numbers rising above each other by equal differences, as 289, 299, 309, or 148, 214, 280, 346, or

307142085345648276198756

which number of 24 places is divisible by 3, being composed of 6 numbers in a series whose common difference is 1137.

of numbers under the first, or side by side, so that the numbers shall stand opposite to one another thus,

1	2	3	4	5	6	7
2	4	8	16	32	64	128

you will find, that if you add together any two of the upper or first set, and go to the number opposite their sum, in the lower or second set, you will have in this last set the number arising from multiplying together the numbers of the lower set corresponding to the numbers added together. Thus, add 2 to 4, you have 6 in the upper set, opposite to which in the lower set is 64, and multiplying the numbers 4 and 16 opposite to 2 and 4, the product is 64. In like manner, if you subtract the upper numbers, and look for the lower numbers opposite to their difference, you obtain the quotient of the lower numbers opposite the number subtracted. Thus, take 4 from 6 and 2 remains, opposite to which you have in the lower line 4; and if you divide 64, the number opposite to 6, by 16, the number opposite to 4, the quotient is 4. The upper set are called the *logarithms* of the lower set, which are called *natural numbers:* and tables may, with a little trouble, be constructed, giving the logarithms of all numbers from 1 to 10,000 and more; so that, instead of multiplying or dividing one number by another, you have only to add or subtract their logarithms, and then you at once find the product or the quotient in the tables. These are made applicable to numbers far higher than any actually in them, by a very simple process; so that you may at once perceive the prodigious saving of time and labour which is thus made. If you had, for instance, to multiply 7,543,283 by itself, and that product again by the original number, you would have to multiply a number of seven places of figures by an equally large number, and then a number of 14 places of figures by one of seven places, till at last you had a product of 21 places of figures—a very tedious operation; but working by logarithms, you would only have to take three times the logarithm of the original number, and that gives the logarithm of the last product of 21 places of figures, without any further multiplication. So much for the time and

trouble saved, which is still greater in questions of division; but by means of logarithms many questions can be worked, and of the most important kind, which no time or labour would otherwise enable us to solve.

Geometry teaches the properties of figure, or particular portions of space, and distances of points from each other. Thus, when you see a triangle, or three-sided figure, one of whose sides is perpendicular to another side, you find, by means of geometrical reasoning respecting this kind of triangle, that if squares be drawn on its three sides, the large square upon the slanting side opposite the two perpendiculars, is exactly equal to the two smaller squares upon the perpendiculars, taken together; and this is absolutely true, whatever be the size of the triangle, or the proportions of its sides to each other. Therefore, you can always find the length of any one of the three sides by knowing the lengths of the other two. Suppose one perpendicular side to be 10 feet long, the other 6, and you want to know the length of the third side opposite to the perpendiculars, you have only to find a number such, that if multiplied by itself, it shall be equal to 10 times 10, together with 6 times 6, that is 136. (This number is between $11\frac{4}{7}$ and $11\frac{5}{7}$.) Now only observe the great advantage of knowing this property of the triangle, or of perpendicular lines. If you want to measure a line passing over ground which you cannot reach—to know, for instance, the length of one side covered with water of a field, or the distance of one point on a lake or bay from the opposite side—you can easily find it by measuring two lines perpendicular to one another on the dry land, and running through the two points; for the line wished to be measured, and which runs through the water, is the third side of a perpendicular-sided triangle, the other two sides of which are ascertained. But there are other properties of triangles, which enable us to know the length of two sides of any triangle, whether it has perpendicular sides or not, by measuring one side and also measuring the inclination of the other two sides to this side, or what is called the two angles made by those sides with the measured side. Therefore you can easily find the

perpendicular line drawn or supposed to be drawn from the top of a mountain through it to the bottom, that is the height of the mountain; for you can measure a line on level ground, and also the inclination of two lines, supposing them drawn in the air, and reaching from the ends of the measured lines to the mountain's top; and having thus found the length of the one of those lines next the mountain, and its inclination to the ground, you can at once find the perpendicular, though you cannot possibly get near it. In the same way, by measuring lines and angles on the ground, and near, you can find the length of lines at a great distance, and which you cannot get near; for instance, the length and breadth of a field on the opposite side of a lake or sea; the distance of two islands, or the space between the tops of two mountains.

Again, there are curve-lined figures as well as straight, and geometry teaches the properties of these also. The best known of all the curves is the circle, or a figure made by drawing a string round a fixed point, and marking where its other end traces, so that every part of the circle is equally distant from the fixed point or centre. From this fundamental property, an infinite variety of others follow by steps of reasoning more or less numerous, but all necessarily arising one out of another. To give an instance; it is proved by geometrical reasoning, that if from the two ends of any diameter of the circle you draw two lines to meet in any one point of the circle whatever, those lines are perpendicular to each other. Another property, and a most useful one is, that the sizes, or areas, of all circles whatever, from the greatest to the smallest, from the sun to a watch-dial-plate, are in exact proportion to the squares of their distances from the centre; that is, the squares of the strings they are drawn with: so that if you draw a circle with a string 5 feet long, and another with a string 10 feet long, the large circle is four times the size of the small one, as far as the space or area enclosed is concerned; the square of 10 or 100 being four times the squares of 5 or 25. But it is also true, that the lengths of the circumferences themselves, the number of feet over which the ends

of the strings move, are in proportion to the lengths of the strings; so that the curve of the larger circle is only twice the length of the curve of the lesser.

But the circle is only one of an infinite variety of curves, all having a regular formation and fixed properties. The *oval* or *ellipse* is, perhaps, next to the circle, the most familiar to us, although we more frequently see another curve line formed by the motions of bodies thrown forward. When you drop a stone, or throw it straight up, it goes in a straight line; when you throw it forward, it goes in a curve line till it reaches the ground; as you may see by the figure in which water runs when forced out of a pump, or from a fire-pipe, or from the spout of a kettle or tea-pot. The line it moves in is called a *parabola;* every point of which bears a certain fixed relation to a certain point within it, as the circle does to its centre. Geometry teaches various properties of this curve; for example, that if the direction in which the stone is thrown, or the bullet fired, or the water spouted, be half the perpendicular to the ground, that is, half way between being level with the ground and being upright, the curve will come to the ground at a greater distance than if any other direction whatever were given with the same force. So that to make the gun carry furthest, or the fire-pipe play to the greatest distance, they must be pointed, not as you might suppose, level or point blank, but about half way between that direction and the perpendicular. If the air did not resist, and so somewhat disturb the calculation, the direction to give the longest range ought to be exactly half perpendicular.

The *oval* or *ellipse*, is drawn by taking a string of any certain length, and fixing, not one end as in drawing the circle, but both ends, and then carrying a point, as a pencil or chalk, round inside the string, always keeping it stretched as far as possible. It is plain, that this figure is as regularly drawn as the circle, though it is very different from it; and you perceive that every point of its curve must be so placed, that the straight lines drawn from it to the two points where the string was fixed, are, when added together, always the same; for they make together the length of the

string. Among various properties belonging to this curve, in relation to the straight lines drawn within it, is one which gives rise to the construction of the *trammels* or elliptic compasses used for making figures and ornaments of this form; and also to the construction of lathes for turning oval frames, and the like.

If you wish at once to see these three curves, take a sugar-loaf, and cut it any where clean through in a direction parallel to its base or bottom; the outline or edge of the loaf where it is cut will be a *circle*. If the cut is made so as to slant, and not be parallel to the base of the loaf, the outline is an *ellipse*, provided the cut goes quite through the sides of the loaf all round; but if it goes slanting, and parallel to the line of the loaf's side, the outline is a *parabola;* and if you cut in any direction not through the sides all round, but through the sides and base, and not parallel to the line of the side, the outline will be another curve of which we have not yet spoken, but which is called an *hyperbola*. You will see another instance of it, if you take two plates of glass, and lay them on one another; then put their edge in water, holding them upright and pressing them together; the water, which, to make it more plain, you may colour with a few drops of ink or strong tea, rises to a certain height, and its outline is this curve; which, however much it may seem to differ in form from a circle or ellipse, is found by mathematicians to resemble them very closely in many of its most remarkable properties.

These are the curve lines best known and most frequently discussed; but there are an infinite number of others all related to straight lines and other curve lines by certain fixed rules; for example, the course which any part, as the nail in the felly of a wheel rolling along takes through the air, is a curve called the *cycloid*, which has many remarkable properties; and, among others, this, that it is, of all lines possible, the one in which any body not falling perpendicularly, will descend from one point to another the most quickly.

II. You perceive, if you reflect a little, that the science which we have been considering in both its branches, has

nothing to do with matter; that is to say, it does not at all depend upon the properties or even upon the existence of any bodies or substances whatever. The distance of one point or place from another is a straight line; and whatever is proved to be true respecting this line, as, for instance, its proportion to other lines of the same kind, and its inclination towards them, what we call the angles it makes with them, would be equally true whether there were any thing in those places, at those two points, or not. So if you find the number of yards in a square field, by measuring one side, 100 yards, and then, multiplying that by itself, which makes the whole area 10,000 square yards, this is equally true whatever the field is, whether corn or grass, or rock or water; it is equally true if the solid part, the earth or water, be removed, for then it would be a field of air bounded by four walls or hedges; but suppose the walls or hedges were removed, and a mark only left at each corner, still it would be true that the space enclosed or bounded by the lines supposed to be drawn between the four marks was 10,000 square yards in size. But the marks need not be there; you only want them while measuring one side; if they were gone, it would be equally true that the lines, supposed to be drawn from the places where the marks had been, enclose 10,000 square yards of air. But if there were no air, and consequently a mere void, or empty space, it would be equally true that this space is of the size you had found it to be by measuring the distance of one point from another, of one of the space's corners or angles from another, and then multiplying that distance by itself. In the same way it would be true, that if the space were circular, its size, compared with another circular space of half its diameter, would be four times larger; of one third its diameter, nine times larger, and of one fourth sixteen times, and so on always in proportion to the squares of the diameters; and that the length of the circumference, the number of feet or yards in the line round the surface, would be twice the length of a circle whose diameter was one half, thrice the circumference of one whose diameter was one third, four times the circum-

ference of one whose diameter was one fourth, and so on, in the simple proportion of the diameters. Therefore every property which is proved to belong to figures belongs to them without the smallest relation to bodies or matter of any kind, although we generally see figures in connexion with bodies; but all those properties would be equally true, if no such thing as matter or bodies existed; and the same may be said of the properties of number, the other great branch of the mathematics. When we speak of twice two, and say it makes four, we affirm this without thinking of two horses, or two balls, or two trees; but two of any thing and every thing equally. Nay, this branch of mathematics may be said to apply still more extensively than even the other; for it has no relation to space, which geometry has; and, therefore, it is applicable to cases where figure and size are wholly out of the question. Thus you can speak of two dreams, or two ideas, or two minds, and can calculate respecting them just as you would respecting so many bodies; and the properties you find belonging to numbers, will belong to those numbers when applied to things that have no outward or visible or perceivable existence, and cannot even be said to be in any particular place, just as much as the same numbers applied to actual bodies which may be seen and touched.

It is quite otherwise with the science which we are now going to consider, *Natural Philosophy.* This teaches the nature and properties of actually existing substances, their motions, their connexions with each other, and their influence on one another. It is sometimes also called *Physics*, from the Greek word signifying *Nature*, though that Greek word is more frequently, in common speech, confined to one particular branch of the science, concerning the bodily health.

We have mentioned one distinction between Mathematics and Natural Philosophy, that the former does not depend on the nature and existence of bodies, which the latter entirely does. Another distinction, and one closely connected with this, is, that the truths which Mathematics teach us are *necessarily* such,—they are truths of them-

selves, and wholly independent of facts and experiments,—they depend only upon reasoning; and it is utterly impossible they should be otherwise than true. This is the case with all the properties which we find belong to numbers and to figures—2 and 2 must of *necessity*, and through all time, and in every place, be equal to 4; those numbers must *necessarily* be always divisible by 3 without leaving any remainder over, which have the sums of the figures they consist of divisible by 3; and circles must *necessarily*, and for ever and ever, be to one another in the exact proportion of the squares of their diameters. It cannot be otherwise; we cannot conceive it in our minds to be otherwise. No man can in his own mind suppose to himself that 2 and 2 should ever be more or less than 4; it would be an utter impossibility—a contradiction in the very ideas. The other properties of number, though not so plain at first sight as this, are proved to be true by reasoning, every one step of which follows from the step immediately before, as a matter of course, and so clearly and unavoidably, that it cannot be supposed or even imagined to be otherwise; the mind has no means of fancying how it could be otherwise: the final conclusion from all the steps of the reasoning or demonstration, as it is called, follows in the same way from the last of the steps, and is therefore just as evidently and necessarily true as the first step, which is always something self-evident, as that 2 and 2 make 4, or that the whole is greater than any of its parts, but equal to all its parts put together. It is by this kind of reasoning, step by step, from the most plain and evident things, that we arrive at the knowledge of other things which seem at first not true, or at least not generally true; but when we do arrive at them, we perceive that they are just as true, and for the same reasons, as the first and most obvious matters; that their truth is absolute and necessary, and that it would be as absurd and self-contradictory to suppose they ever could, under any circumstances, be not true, as to suppose that 2 added to 2 could ever make 3, or 5, or 100, or any thing but 4; or, which is the same thing, that 4 should ever be equal to 3, or 5, or 100, or any thing but 4.

To find out these reasonings, to pursue them to their consequences, and thereby to discover the truths which are not immediately evident, is what science teaches us; but when the truth is once discovered, it is as certain and plain by the reasoning, as the first truths themselves from which all the reasoning takes its rise, on which it all depends, and which require no proof because they are self-evident at once, the instant they are understood.

But it is quite different with the truths which Natural Philosophy teaches. All these depend upon matter of fact; and that is learnt by observation and experiment, and never could be discovered by reasoning at all. If a man were shut up in a room with pen, ink, and paper, he might by thought discover any of the truths in arithmetic, algebra, or geometry; it is possible, at least; there would be nothing absolutely impossible in his discovering all that is now known of these sciences; and if his memory were as good as we are supposing his judgment and conception to be, he might discover it all without pen, ink, and paper, and in a dark room. But we cannot discover a single one of the fundamental properties of matter without observing what goes on around us, and trying experiments upon the nature and motion of bodies. Thus, the man whom we have supposed shut up could not possibly find out beyond one or two of the very first properties of matter, and those only in a very few cases; so that he could not tell if these were general properties of all matter or not. He could tell that the objects he touched in the dark were hard and resisted his touch; that they were extended and were solid; that is, that they had three dimensions, length, breadth, and thickness. He might guess that other things existed beside those he felt, and that those other things resembled what he felt in these properties, but he could know nothing for certain, and could not even conjecture much beyond this very limited number of qualities. He must remain utterly ignorant of what really exists in nature, and of what properties matter in general has. These properties, therefore, we learn by experience; they are such as we know bodies to have; they happen to have them—they

are so formed by Divine Providence as to have them—but they might have been otherwise formed; the great Author of Nature might have thought fit to make all bodies different in every respect. We see that a stone dropped from our hand falls to the ground; this is a fact which we can only know by experience; before observing it, we could not have guessed it, and it is quite *conceivable* that it should be otherwise; for instance, that when we remove our hand from the body it should stand still in the air; or fly upward, or go forward, or backward, or sideways; there is nothing at all absurd, contradictory, or inconceivable in any of these suppositions; there is nothing impossible in any of them, as there would be in supposing the stone equal to half of itself, or double of itself; or both falling down and rising upwards at once; or going to the right and the left at one and the same time. Our only reason for not at once thinking it quite conceivable that the stone should stand in the air, or fly upwards, is, that we have never seen it do so, and have become accustomed to see it do otherwise. But for that, we should at once think it as natural that the stone should fly upwards or stand still, as that it should fall. But no degree of reflection for any length of time could accustom us to think 2 and 2 equal to any thing but 4, or the whole to be equal to a part.

After we have once by observation or experiment ascertained certain things to exist in fact, we may then reason upon them by means of mathematics; that is, we may apply mathematics to our experimental philosophy, and then such reasoning becomes absolutely certain, taking the fundamental facts for granted. Thus, if we find that a stone falls in one direction when dropped, and we further observe the peculiar way in which it falls, that is, quicker and quicker every instant till it reaches the ground, we learn the rule or the proportion by which the quickness goes on increasing; and we further find, that if the same stone is pushed forward on a table, it moves in the direction of the push, till it is either stopped by something, or comes to a pause, by rubbing against the table, and being hindered by the air. These are all facts which we learn by observing

and trying, and they might all have been different if matter and motion had been otherwise constituted; but supposing them to be as they are, and as we find them, we can, by reasoning mathematically from them, find out many most curious and important truths depending upon these facts, and depending upon them not accidentally, but of necessity. For example, we can find, in what course the stone will move, if, instead of being dropped to the ground, it is thrown forward: it will go in the curve already mentioned, the parabola, and it will run through that curve in a peculiar way, so that there will always be a certain proportion between the time it takes and the space it moves through, and the time it would have taken, and the space it would have moved through had it fallen from the hand to the ground. So we can prove, in like manner, what we before stated of the relation between the distance at which it will come to the ground, and the direction it is thrown in; the distance being greatest of all when the direction is nearly half way between the level or horizontal and the upright or perpendicular. These are mathematical truths, derived by mathematical reasoning upon physical grounds; that is, upon matter of fact found to exist by actual observation and experiment. The result, therefore, is necessarily true, and proved to be so by reasoning only, provided we have once ascertained the facts; but taken altogether, the result depends partly on the facts learned by experiment or experience, partly on the reasoning from these facts. Thus it is found to be true by reasoning, and necessarily true, that *if* the stone falls in a certain way when unsupported, it must when thrown forward go in the curve called a parabola: this is a necessary or mathematical truth, and it cannot possibly be otherwise. But when we state the matter without any supposition,—without any "*if*,"—and say, a stone thrown forward goes in the curve called a parabola, we state a truth, partly fact, and partly drawn from reasoning on the fact; and it might be otherwise if the nature of things were different. It is called a proposition or truth in Natural Philosophy; and as it is discovered and proved by mathematical reasoning, it is

sometimes called a proposition or truth in the *Mixed Mathematics*. The man in the dark room could never discover this truth unless he had been first informed, by those who had observed the fact, in what way the stone falls when unsupported, and moves along the table when pushed. These things he never could have found out by reasoning; they are facts, and he could only reason from them after learning them, by his own experience, or taking them on the credit of other people's experience. But having once so learnt them, he could discover by reasoning merely, and with as much certainty as if he lived in daylight, and saw and felt the moving body, that the motion is in a parabola, and governed by certain rules. As experiment and observation are the great sources of our knowledge of Nature, and as the judicious and careful making of experiments is the only way by which her secrets can be known, Natural and Experimental Philosophy mean one and the same thing; mathematical reasoning being applied to certain branches of it, particularly those which relate to motion and pressure.

III. *Natural Philosophy*, in its most extensive sense, has for its province the investigation of the laws of matter; that is, the properties and the motions of matter; and may be divided into two great branches. The first and most important (which is sometimes on that account called *Natural Philosophy*, but more properly *Mechanical Philosophy*,) investigates the sensible motions of all bodies. The second investigates the constitution and qualities of all bodies, and has various names, according to its different objects. It is called *Chemistry*, if it teaches the properties of bodies with respect to heat, mixture together, weight, taste, appearance, and so forth: *Anatomy* and *Animal Physiology*, if it teaches the structure and functions of living bodies, especially the human, for when it shows those of other animals, we term it *Comparative Anatomy*: *Medicine*, if it teaches the nature of diseases, and the means of preventing them and of restoring health: *Zoology*, (from the Greek words signifying *to speak of animals*,) if it teaches the arrange-

ment or classification and the habits of the different lower animals: *Botany*, if it teaches the arrangement or classification and habits of plants: *Geology*, (from the Greek words meaning *to speak of the earth*,) including *Mineralogy*, if it teaches the arrangement of minerals, the structure of the masses in which they are found, and of the earth composed of those masses. The term *Natural History* is given to the three last branches taken together, but chiefly as far as relates to the classification of different things, or the observation of the resemblances and differences of the various animals, plants, and inanimate and ungrowing substances in nature.

But here we may make two general observations. The *first* is, that every such distribution of the sciences is necessarily imperfect; for one runs unavoidably into another. Thus, Chemistry shows the qualities of plants with relation to other substances, and to each other; and Botany does not overlook those same qualities, though its chief object be arrangement. So Mineralogy, though principally conversant with classifying metals and earths, yet regards also their qualities in respect of heat and mixture. So, too, Zoology, beside arranging animals, describes their structures, like Comparative Anatomy. In truth, all arrangement and classifying depends upon noting the things in which the objects agree and differ; and among those things, in which animals, plants, and minerals agree, must be considered the anatomical qualities of the one and the chemical qualities of the other. From hence, in a great measure, follows the *second* observation, namely, that the sciences mutually assist each other. We have seen how Arithmetic and Algebra aid Geometry, and how both the purely Mathematical Sciences aid Mechanical Philosophy. Mechanical Philosophy, in like manner, assists, though, in the present state of our knowledge, not very considerably, both Chemistry and Anatomy, especially the latter; and Chemistry very greatly assists both Physiology, Medicine, and all the branches of Natural History.

The first great head, then, of Natural Science, is Mechanical Philosophy; and it consists of various subdivi-

sions, each forming a science of great importance. The most essential of these, and which is indeed fundamental, and applicable to all the rest, is called ***Dynamics***, from the Greek word signifying *power* or *force*, and it teaches the laws of motion in all its varieties. The case of the stone thrown forward, which we have already mentioned more than once, is an example. Another, of a more general nature, but more difficult to trace, and far more important in its consequences, and of which, indeed, the former is only one particular case, relates to the motions of all bodies, which are attracted (or influenced, or drawn) by any power towards a certain point, while they are, at the same time, driven forward by some push given to them at first; and continuing to act on them while they are drawn towards the point. The line in which a body moves while so drawn and so driven, depends upon the force it is pushed with, the direction it is pushed in, and the kind of power that draws it towards the point; but, at present, we are chiefly to regard the latter circumstance, the attraction towards the point. If this attraction be uniform, that is, the same at all distances from the point, the body will move in a circle, and the point to which it is constantly drawn will be the centre of the circle. Thus, a stone in a sling, when whirled round the hand, moves for this reason in a circle, while it remains in the sling; the force that draws it towards the hand being always the same, and the hand either stopping after setting the stone a-whirling, in which case it is the centre of the circle, or going round in a smaller circle, in which case the point is the centre of the two circles, the one the stone whirls round in, and the one the hand moves round in. (Of course we speak not now of the line the stone moves in after leaving the sling; that is a parabola, as before stated.) If the force that draws the moving body changes at different distances, so as to make the body move quicker, by drawing it more strongly towards the point, the nearer it is to that point, then the body will move, not in a circle, but in other curve lines of various kinds, according as the proportion of the force to the distance varies, and according also to the direction of the

forward push, and the force with which it was originally given. If the force drawing towards the point is such, that, at two feet from the point, it is four times less than at one foot; at three feet, nine times less; at four feet sixteen times less; and so on, always lessening in the same proportion, that is, as the squares of the distances increase; and if the body is pushed forward with a particular degree of force; the line in which it moves will go round the point, but it will not be a circle; it will be an oval or ellipse; the curve described by means of a cord fixed at both ends, in the way we have already explained; the point of attraction will be nearer one end of the ellipse than the other, and the time the body will take to go round, compared with the time any other body would take, moving at a different distance from the same point of attraction, but drawn towards that point with a force which bears the same proportion to the distance, will bear a certain proportion, discovered by mathematicians, to the average distances of the two bodies from the point of common attraction. If you multiply the numbers expressing the times of going round each by itself, the products will be to one another in the proportion of the average distances multiplied each by itself, and that product again by the distance. Thus, if one body take two hours, and is five yards distant, the other, being ten yards off, will take something less than five hours and forty minutes.

Now, this is one of the most important truths in the whole compass of science; for it does so happen, that the force with which bodies fall towards the earth, or what is called their *gravity*, the power that draws or attracts them towards the earth, varies with the distance exactly in the proportion of the squares, lessening as the distance increases:—at two miles from the earth, it is four times less than at one mile; at three miles, nine times less; and so forth. It goes on lessening, but never is destroyed, even at the greatest distances to which we can reach, and there can be no doubt of its extending indefinitely beyond. But, by astronomical observations made upon the motion of the heavenly bodies, upon that of the moon for instance, it is

proved that her movement is slower and quicker at different parts of her course, in the same manner as a body's motion on the earth would be slower and quicker, according to its distance from the point it was drawn towards, provided it was drawn by a force acting in the proportion to the squares of the distance, which we have frequently mentioned; and the proportion of the time to the distance is also observed to agree with the rule we have referred to. Therefore, she is shown to be attracted towards the earth by a force that varies according to the same proportion in which gravity varies; and she must consequently move in an ellipse round the earth, which is placed in a point nearer the one end than the other of that curve. In like manner, it is shown that the earth moves round the sun in the same curve line, and is drawn towards the sun by the same force; and that all the other planets in their courses, at various distances, follow the same rule, moving in ellipses, and drawn towards the sun by the same kind of power. Three of them have moons like the earth, only more numerous, for Jupiter has four, Saturn seven, and Herschel six, so very distant that we cannot see them without the help of glasses; but all those moons move round their principal planets, as ours does round the earth, in ovals or ellipses; while the planets, with their moons, move in their ovals round the sun, like our own earth with its moon. But this power, which draws them all towards the sun, and regulates their path and their motion round him, and which draws the moons towards the principal planets, and regulates their motion and path round those planets, is the same with the gravity by which bodies fall towards the earth, being attracted by it. Therefore, the whole of the heavenly bodies are kept in their places, and wheel round the sun, by the same influence or power that makes a stone fall to the ground.

It is usual to call the sun, and the planets which with their moons move round him, (twelve in number, including the four lately discovered, and the one discovered by Herschel,) the *Solar System*, because they are a class of the heavenly bodies far apart from the innumerable fixed stars,

and so near each other as to exert a perceptible influence on one another, and thus to be connected together. The *Comets* belong to the same system, according to this manner of viewing the subject. They are bodies which move in elliptical paths, but far longer and narrower than the curves in which the earth, and the other planets and their moons roll. Our curves are not much less round than circles; the paths of the comets are long and narrow, so as, in many places, to be more nearly straight lines than circles. They differ from the planets and their moons in another respect; they do not depend on the sun for the light they give, as our moon plainly does, being dark when the earth comes between her and the sun; and as the other planets do, those of them that are nearer the sun than we are, being dark when they come between us and him. But the comets give light always of themselves, being apparently vast bodies heated red-hot by coming in their course far nearer the sun than the nearest of the planets ever do. Their motion is much more rapid than that of the planets: they both approach the sun much nearer, retreat from him to much greater distances, and take much longer time in going round him than any of the planets do. Yet even these comets are subject to the same great law of gravitation, which regulates the motions of the planets. Their year, the time they take to revolve, is in some cases 75, in others 135, in others 300 of our years; their distance is a hundred times our distance when furthest off, and not a hundred and sixtieth of our distance when nearest the sun; their swiftest motion is above twelve times swifter than ours, although ours is a hundred and forty times swifter than a cannon ball's; yet their path is a curve of the same kind with ours, though longer and flatter, differing in its formation only as one oval differs from another by the string you draw it with having the ends fixed at two points more distant from each other; consequently the sun, being in one of those points, is much nearer the end of the path the comet moves in, than he is near the end of our path. The motion, too, follows the same rule, being swifter the nearer the sun; the attraction of the sun varies ac-

cording to the squares of the distances, being four times less at twice the distance, nine times less at thrice, and so on; and the proportion between the times of revolving and the distances is exactly the same, in the case of those remote bodies, as in that of the moon and the earth. One law prevails over all, and regulates their motions as well as our own; it is the gravity of the comets towards the sun, and they, like our own earth and moon, wheel round him in boundless space, drawn by the same force, acting by the same rule, which makes a stone fall when dropped from the hand.

The more full and accurate our observations are upon these heavenly bodies, the better we find all their motions agreeing with this great doctrine; although, no doubt, many things are to be taken into the account beside the force that draws them to their different centres: thus, while the moon is drawn by the earth, and the earth by the sun, the moon is also drawn directly by the sun; and while Jupiter is drawn by the sun, so are his moons; and both Jupiter and his moons are drawn by Saturn: nay, as this power of gravitation is quite universal, and as no body can attract or draw another without being itself drawn by that other, the earth is drawn by the moon, while the moon is drawn by the earth; and the sun is attracted by the planets which he draws towards himself. These mutual attractions give rise to many deviations from the simple line of the ellipse, and produce many irregularities in the simple calculation of the times and motions of the bodies that compose the system of the universe. But the extraordinary powers of investigation applied to the subject by the modern improvements in Mathematics, have enabled us at length to reduce even the greatest of the irregularities to order and system; and to unfold one of the most wonderful truths in all science, namely, that by certain necessary consequences of the simple fact upon which the whole fabric rests,—the proportion of the attractive force to the distances at which it operates,—all the irregularities which at first seemed to disturb the order of the system, and to make the appearances depart from the doctrine, are them-

selves subject to a certain fixed rule, and can never go beyond a particular point, but must begin to lessen when they have slowly reached that point, and then lessen until they reach another point, when they begin again to increase; and so on, for ever. Thus, the planets move in ovals, from gravity, the power that attracts them, towards the sun, combined with the original impulse they received forwards; and the disturbing forces are continually varying the course of the curves or ovals, making them bulge out in the middle, as it were, on the sides, though in a very small proportion to the whole length of the ellipse. The oval thus bulging, however, its length never alters, only its breadth, and that breadth increases by a very small quantity yearly and daily; after a certain number of years it becomes as great as it ever can be; then the alteration takes a contrary direction, and the curve gradually flattens as it had bulged; till, in the same number of years which it took to bulge, it becomes as flat as it ever can be, and then it begins to bulge again, and so on for ever; and so of every other disturbance and irregularity in the system. What at first appears to be some departure from the rule, when more fully examined, turns out to be only a consequence of it, or a result of a more general arrangement springing from the principle of gravitation; an arrangement of which the rule itself, and the apparent or supposed exception, form parts.

The power of gravitation, which thus regulates the whole system of the universe, is found to rule each member or branch of it separately. Thus, it is demonstrated, that the tides of the ocean are caused by the gravitation which attracts the water towards the sun and moon; and the figure both of our earth and of such of the other bodies as have a spinning motion round their axis, is determined by gravitation; they are all flattened towards the ends of the axis they spin upon, and bulge out towards the middle.

The great discoverer of the principle on which all these truths rest, Sir Isaac Newton, certainly by far the most extraordinary man that ever lived, concluded by reasoning upon the nature of motion and matter that this flattening

must take place in our globe: every one before his time had believed the earth to be a perfect sphere or globe, chiefly from observing the round shadow which it casts on the moon in eclipses; and it was many years after his death that the accuracy of his opinion was proved by measurements on the earth's surface, and by the different weight and attraction of bodies at the equator, where it bulges, and at the poles, where it is flattened. The improved telescopes have enabled us to ascertain the same fact with respect to the planets Jupiter and Saturn.

Beside unfolding the general laws which regulate the motions and figures of the heavenly bodies forming our solar system, Astronomy consists in calculations of the places, times, and eclipses of those bodies, and their moons or *satellites*, (from a Latin word, signifying an *attendant;*) and in observations of the fixed stars, which are innumerable assemblages of bodies, not moving round the sun as our earth and the other planets do, nor receiving the light they shine with from his light; but shining, as the sun and the comets do, with a light of their own; and placed, to all appearance, immoveable, at immense distances from our world, that is, from our solar system. Each of them is probably the sun of some other system like our own, composed of planets and their moons, or satellites; but so extremely far off from us, that they all are seen by us like one point of faint light, as you see two lamps, placed a few inches asunder, only like one, when you view them a great way off. The numbers of the fixed stars are prodigious; even to the naked eye they are very numerous, about 3000 being thus visible; but when the heavens are viewed through the telescope, stars become visible in numbers wholly incalculable: 2000 are discovered in one of the small collections of a few visible stars called *Constellations;* nay, what appears to the naked eye only a light cloud, as the *Milky Way*, when viewed through a telescope, proves to be an assemblage of innumerable fixed stars, each of them in all likelihood a sun and a system like the rest, though at an immeasurable distance from ours.

The size, and motions, and distances of the heavenly

bodies are such as to exceed the power of ordinary imagination, from any comparison with the smaller things we see around us. The earth's diameter is nearly 8000 miles in length; but the sun's is above 880,000 miles, and the bulk of the sun is above 1,300,000 times greater than that of the earth. The planet Jupiter, which looks like a mere speck, from his vast distance, is nearly 1300 times larger than the earth. Our distance from the sun is above 95 millions of miles; but Jupiter is 490 millions, and Saturn 900 millions of miles distant from the sun. The rate at which the earth moves round the sun is 68,000 miles an hour, or 140 times swifter than the motion of a cannon-ball; and the planet Mercury, the nearest to the sun, moves still quicker, nearly 110,000 miles an hour. We, upon the earth's surface, beside being carried round the sun, move round the earth's axis by the rotatory or spinning motion which it has; so that every 24 hours we move in this manner near 14,000 miles, beside moving round the sun above 1,600,000 miles. These motions and distances, however, prodigious as they are, seem nothing compared to those of the comets, one of which, when furthest from the sun, is 11,200 millions of miles from him; and when nearest the sun, flies at the amazing rate of 880,000 miles an hour. Sir I. Newton calculated its heat at 2000 times that of red-hot iron; and that it would take thousands of years to cool. But the distance of the fixed stars is yet more vast: they have been supposed to be 400,000 times further from us than we are from the sun, that is 38 millions of millions of miles: so that a cannon-ball would take between four and five millions of years to reach one of them, supposing there was nothing to hinder it from pursuing its course thither.

Astronomers have, by means of their excellent glasses, aided by Geometry and calculation, been able to observe not only stars, planets, and their satellites, invisible to the naked eye, but to measure the height of mountains in the moon by observations of the shadows which these eminences cast on her surface; and they have discovered volcanoes, or burning mountains, on the same body.

The tables which they have by the same means been enabled to form of the heavenly motions, are of great use in navigation. By means of the eclipses of Jupiter's satellites, and by the tables of the moon's motion, we can ascertain the position of a ship at sea; for the observation of the sun's height at mid-day gives the *latitude* of the place, that is, its distance from the equinoctial or equator, the line passing through the middle of the earth's surface; and these tables, with the observations of the satellites, or moons, give the distance east and west of the observatory for which the tables are calculated; what is called the *longitude* of the place: consequently the mariner can thus tell nearly in what part of the ocean he is, how far he has sailed from his port of departure, and how far he must sail, and in what direction, to gain the port of his destination. The advantage of this knowledge is therefore manifest in the common affairs of life; but it sinks into insignificance compared with the vast extent of those views which the contemplations of the science afford, of numberless worlds filling the immensity of space, and all kept in their places, and adjusted in their prodigious motions by the same simple principle, under the guidance of an all-wise and all-powerful Creator.

We have been considering the application of Dynamics to the motions of the heavenly bodies, which forms the science of *Physical Astronomy*. The application of Dynamics to the calculation, production, and direction of motion, forms the science of *Mechanics*, sometimes called *Practical Mechanics*, to distinguish it from the more general use of the word, which comprehends every thing that relates to motion and force. The fundamental principle of the science upon which it mainly depends, flows immediately from a property of the circle already mentioned, and which, perhaps, appeared at the moment of little value, that the lengths of circles are in proportion to their diameters. Observe how, upon this simple truth, nearly the whole of those contrivances are built by which the power of man is increased, as far as solid matter assists him in extending it; and nearly the whole of those doctrines, too, by which he

is enabled to explain the voluntary motions of animals, as far as those depend upon their own bodies. There can be nothing more instructive in showing the importance and fruitfulness of scientific truths, however trivial and forbidding they may at first sight appear. For it is an immediate consequence of this property of the circle, that if a rod of iron, or beam of wood, or any other such solid material, be placed on a point or pivot, so that it may move as the arms of a balance do round its centre, or a see-saw board does round its prop, the two ends will go through parts of circles, each proportioned to that arm of the beam to which it belongs; the two circles will be equal if the pivot is in the centre or middle point of the beam; but if it is nearer one end than the other, say three times, that end will go through a circular space, or arch, three times shorter than the circular space the other end goes through in the same time. If, then, the end of the long beam goes through three times the space, it must move with three times the swiftness of the short beam's end, since both move in the same time; and therefore any force applied to the long end must overcome the resistance of three times that force applied at the opposite end, since the two ends move in contrary directions; hence one pound placed at the long end would balance three placed at the short end. The beam we have been supposing is called a *Lever*, and the same rule must evidently hold for all proportions of the lengths of its beams. If, then, the lever be 17 feet long, and the pivot, or *fulcrum*, (as it is called, from a Latin word signifying *support*,) be a foot from one end, an ounce placed on the other end will balance a pound placed on the near end; and the least additional weight, or the slightest push or pressure on the far end, so loaded, will make the pound weight on the other move upwards. If, instead of an ounce, we place upon the long end the short end of a second beam or lever supported by a fulcrum, one foot from it, and then place the long end of this second lever upon the short end of a third lever, whose fulcrum is one foot from it; and if we put on the end of this third lever's long arm an ounce weight, that ounce will move upwards a

pound on the second lever's long arm, and this moving upwards will cause the short arm to force downwards 16 pounds at the long end of the first lever, which will make the short end of the first lever move upwards, though 256 pounds be laid on it; the same thing continuing, a pound on the long end of the third lever will move a ton and three quarters at the short end of the first lever; that is, will balance it so that the slightest touch or pressure with the finger, or a touch from a child's hand will move as much as two horses can draw. The lever is called on this account a *mechanical power;* and there are five other mechanical powers of which its properties form the foundation; indeed they may be resolved into combinations of levers. Thus the wheel and axle is only a lever moving round an axle, and always retaining the effect gained during every part of the motion, by means of a rope wound round the butt end of the axle; the spoke of the wheel being the long arm of the lever, and the half diameter of the axle its short arm. By a combination of levers, wheels, pullies, so great an increase of force is obtained, that, but for the obstruction from friction, and the resistance of the air, there could be no bounds to the effect of the smallest force thus multiplied; and to this fundamental principle, Archimedes, one of the most illustrious mathematicians of ancient times, referred, when he boasted, that if he only had a pivot or fulcrum whereon he might rest his machinery, he could move the earth. Upon so simple a truth, assisted by the aid derived from other means, rests the whole fabric of mechanical power, whether for raising weights, or cleaving rocks, or pumping up rivers, from the bowels of the earth; or, in short, performing any of those works to which human strength, even augmented by the help of the animals whom Providence has subdued to our use, would prove altogether inadequate.

The application of Dynamics to the pressure and motions of fluids, constitutes a science which receives different appellations according as the fluids are heavy and liquid like water, or light and invisible like air. In the former case it is called *Hydrodynamics*, from the Greek words

signifying *water* and *power*, or *force;* in the latter *Pneumatics*, from the Greek word signifying *breath* or *air ;* and Hydrodynamics is divided into *Hydrostatics*, which treats of the weight and pressure of liquids, from the Greek words for *balancing* of *water*, and *Hydraulics*, which treat of their motion, from the Greek name for certain musical instruments played with *water* in *pipes*.

The discoveries to which experiments, aided by mathematical reasoning, have led, upon the pressure and motion of fluids, are of the greatest importance, whether we regard their application to practical purposes, or to the explanation of the appearances in nature, or their singularity as the subjects of scientific contemplation. When it is found that the pressure of water upon any surface that contains it, is not in the least degree proportioned to its bulk, but only to the height at which it stands, so that a long small pipe-full, containing a pound or two of water, will give the pressure of twenty or thirty ton; nay, of twice or thrice as much, if its length be increased, and its bore lessened, without the least regard to the quantity of the liquid: we are not only astonished with so extraordinary and unexpected a property of matter, but we at once perceive one of the great agents employed in the vast operations of nature, in which the most trifling means are used to work the mightiest effects. We likewise learn to guard against many serious mischiefs in our own works, and to apply safely and usefully a power calculated, according as it is directed, either to produce unbounded devastation, or to render the most beneficial service.

Nor are the discoveries relating to the Air less interesting in themselves, and less applicable to important uses. It is an agent, though invisible, as powerful as water, both in the operations of nature and of art. Experiments of a simple and decisive nature show the amount of its pressure to be between 14 and 15 pounds on every square inch; but, like all other fluids, it presses equally in every direction; so that, though on our hand there is a pressure downwards of above 250 pounds, yet this is exactly balanced by an equal pressure upwards, from the air pressing

round and getting below. If, however, the air be removed below, the whole pressure from above acts unbalanced: hence the ascent of water in pumps, which suck out the air from a barrel, and allow the pressure upon the water to force it up 32 or 33 feet, that body of water being equal to the weight of the atmosphere; hence the ascent of the mercury in the barometer but only 28 or 29 inches, mercury being between 13 and 14 times heavier than water. Hence, too, the motion of the steam-engine; the piston of which is pressed downwards by the weight of the atmosphere from above, all air being removed below it by first filling it with steam, and then suddenly cooling and converting that steam into water. Hence, too, the power which some animals possess of walking along the perpendicular surfaces of walls, and even the ceilings of rooms, by squeezing out the air between the inside of their feet and the surface of the wall, and thus being supported by the pressure of the air against the outside of their feet.

The science of *Optics*, (from the Greek word for *seeing*,) which teaches the nature of light, and of the sensation conveyed by it, presents, of itself, a field of unbounded extent and interest. To it the arts, and the other sciences, owe those most useful instruments which have enabled us at once to examine the minutest parts of the structure of animal and vegetable bodies, and to calculate the size and the motions of the most remote of the heavenly bodies. But as an object of learned curiosity, nothing can be more singular than the fundamental truth discovered by the genius of Newton,—that the light, which we call white, is in fact composed of all the colours, blended in certain proportions; unless, perhaps, it be that astonishing conjecture of his unrivalled sagacity, by which he descried the inflammable nature of the diamond, and its belonging, against all appearance of probability, to the class of oily substances, by observing that it stood among them, and far removed from all crystals, in the degree of its action upon light; a conjecture turned into certainty by discoveries made a century afterwards.

To a man who, for original genius and strong natural

sense, is not unworthy of being named after this illustrious sage, we owe the greater part of *Electrical* science. It treats of the peculiar substance, resembling both light and heat, which, by rubbing, is found to be produced in a certain class of bodies, as glass, wax, silk, amber; and to be conveyed easily or *conducted* through others, as wood, metals, water; and it has received the name of *Electricity* from the Greek word for *amber*. Dr. Franklin discovered that this is the same matter which, when collected in the clouds, and conveyed from them to the earth, we call *lightning*, and whose noise, in darting through the air, is *thunder*. The observation of some movements in the limbs of a dead frog gave rise to the discovery of *Animal Electricity* or *Galvanism*, as it was at first called from the name of the discoverer; and which has of late years given birth to improvements that have changed the face of chemical philosophy; affording a new proof how few there are of the processes of nature, incapable of repaying our labour, bestowed in patiently and diligently examining them. It is to the results of the remark accidentally made upon the twitching in the frog's leg, not, however, hastily dismissed, and forgotten, but treasured up and pursued through many an elaborate experiment and calculation, that we owe our acquaintance with the extraordinary metal, liquid like mercury, lighter than water, and more inflammable than phosphorus, which forms when it burns, by mere exposure to the air, one of the salts best known in commerce, and the principal ingredient in saltpetre.

In order to explain the nature and objects of those branches of Natural Science more or less connected with the mathematics, some details were necessary, as without them it was difficult at once to perceive their importance, and, as it were, relish the kind of instruction which they afford. But the same course needs not be pursued with respect to the other branches. The value and the interest of Chemistry is at once perceived, when it is known to teach the nature of all substances, the relations of simple substances to heat and to one another, or their combinations together; the composition of those which nature pro-

duces in a compound state, and the application of the whole to the arts and manufactures. Some branches of philosophy, again, are chiefly useful and interesting to particular classes, as surgeons and physicians. Others are easily understood by a knowledge of the principles of Mechanics and Chemistry, of which they are applications and examples; as those which teach the structure of the earth and the changes it has undergone; the motions of the muscles, and the structure of the parts of animals; the qualities of animal and vegetable substances; and that department of Agriculture which treats of soils, manure, and machinery. Other branches are only collections of facts, highly curious and useful indeed, but which any one who reads or listens, perceives as clearly, and comprehends as readily, as the professed student. To this class belongs Natural History, in so far as it describes the habits of animals and plants, and its application to that department of Agriculture which treats of cattle and their management.

IV. But, for the purpose of further illustrating the advantages of Philosophy, its tendency to enlarge the mind, as well as to interest it agreeably, and afford pure and solid gratification, a few instances may be given of the singular truths brought to light by the application of mathematical, mechanical, and chemical knowledge to the habits of animals and plants; and some examples may be added of the more ordinary and easy, but scarcely less interesting observations, made upon those habits, without the aid of the profounder sciences.

We may remember the curve line which mathematicians call a cycloid. It is the path which any point of a circle, moving along a plane, and round its centre, traces in the air; so that the nail on the felly of a cart-wheel moves in a cycloid, as the cart goes along, and as the wheel itself both turns round its axle, and is carried along the ground. Now this curve has certain properties of a peculiar and very singular kind with respect to motion. One is, that if any body whatever moves in a cycloid by its own weight or swing, together with some other force acting upon it, it

will go through all distances of the same curve in exactly the same time; and, accordingly, pendulums are contrived to swing in such a manner, that they shall describe cycloids, or curves very near cycloids, and thus move in equal times, whether they go through a long or a short part of the same curve. Again, if a body is to descend from any one point to any other, not in the perpendicular, by means of some force acting on it together with its weight, the line in which it will go the quickest of all will be the cycloid, not the straight line, though that is the shortest of all lines which can be drawn between the two points; nor any other curve whatever, though many are much flatter and therefore shorter than the cycloid—but the cycloid, which is longer than them, is yet of all curves or straight lines which can be drawn, the one the body will move through in the shortest time. Suppose the body is to move from one point to another, by its weight and some other force acting together, but to go through a certain space, as a hundred yards, the way it must take to do this in the shortest time possible, is by moving in a cycloid; or the length of a hundred yards must be drawn into a cycloid, and then the body will descend through the hundred yards in a shorter time than it could go the same distance in any other path whatever. Now, it is believed that birds which build in the rocks, drop or fly down from height to height in this course. It is impossible to make very accurate observations on their flight and path; but there is a general resemblance certainly between the course they take and the cycloid, which has led ingenious men to adopt this opinion.

If we have a certain quantity of any substance, a pound of wood, for example, and would fashion it in the shape to take the least room, we must make a globe of it; it will in this figure have the smallest surface. But suppose we want to form the pound of wood, so that in moving through the air or water it shall meet with the least possible resistance, then we must lengthen it out for ever, till it becomes not only like a long-pointed pin, but thinner and thinner, longer and longer, till it is quite a straight line, and has no

perceptible breadth or thickness at all. If we would dispose of the given quantity of matter so that it shall have a certain length only, say a foot, and a certain breadth at the thickest part, say three inches, and move through the air or water with the smallest possible resistance which a body of those dimensions can meet, then we must form it into a figure of a peculiar kind, called the *Solid of least resistance*, because of all the shapes that can be given to the body, its length and breadth remaining the same, this is the one which will make it move with the least resistance through the air, or water, or other fluid. A very difficult chain of mathematical reasoning, by means of the highest branches of algebra, leads to a knowledge of the curve, which by revolving on its axis makes a solid of this shape, in the same way that a circle by so revolving makes a sphere or globe; and the curve certainly resembles closely the face or head part of a fish. Nature, therefore, (by which we always mean the Divine Author of nature,) has fashioned these fishes so, that, according to mathematical principles, they swim the most easily through the element they live and move in.

Suppose upon the face part of one of these fishes a small insect were bred, endowed with faculties sufficient to reason upon its condition, and upon the motion of the fish it belonged to, but never to have discovered the whole size and shape of the face part, it would certainly complain of the form as clumsy, and fancy that it could have made the fish so as to move with less resistance. Yet if the whole shape were disclosed to it, and it could discover the principle on which that shape was preferred, it would at once perceive, not only that what had seemed clumsy was skilfully contrived, but that if any other shape whatever had been taken, there would have been an error committed; nay, *that there must of necessity* have been an error; and that the very best possible arrangement had been adopted. So it may be with man in the Universe, where, seeing only a part of the great system, he fancies there is evil; and yet, if he were permitted to survey the whole, what had seemed imperfect might appear to be necessary for the

general perfection, insomuch that any other arrangement, even of that seemingly imperfect part, must needs have rendered the whole less perfect. The common objection is, that what seems evil might have been avoided; but in the case of the fish's shape it *could not* have been avoided.

It is found by optical inquiries, that the rays or particles of light, in passing through transparent substances of a certain form, are bent to a point where they make an image or picture of the shining bodies they come from, or of the dark bodies they are reflected from. Thus, if a pair of spectacles be held between a candle and the wall, they make two images of the candle upon it; and if they be held between the window and a sheet of paper when the sun is shining, they will make a picture on the paper of the houses, trees, fields, sky, and clouds. The eye is found to be composed of several natural magnifiers which make a picture on a membrane at the back of it, and from this membrane there goes a nerve to the brain, conveying the impression of the picture, by means of which we see it. Now, white light was discovered by Newton to consist of different-coloured parts, which are differently bent in passing through transparent substances, so that the lights of different colours come to a point at different distances, and thus create an indistinct image. This was long found to make our telescopes imperfect, insomuch that it became necessary to make them of reflectors or mirrors, and not of magnifying glasses—the same difference not being observed to affect their reflection. But another discovery was about fifty years afterwards made by Mr. Dollond, that by combining different kinds of glass in a compound magnifier, the difference may be greatly corrected; and on this principle he constructed his telescopes. It is found, too, that the different natural magnifiers of the eye are combined upon a principle of the same kind. Thirty years later, a third discovery was made by Mr. Blair, of the greatly superior effect which combinations of different liquids have in correcting the imperfection; and, most wonderful to think, when the eye is examined, we find it

consists of different liquids, acting naturally upon the same principle which was thus recently found out in Optics by many ingenious mechanical and chemical experiments.

Again, the point to which any magnifier collects the light is more or less distant as the magnifier is smaller or rounder, so that a small globe of glass or any transparent substances makes a microscope. And this property of light depends upon the nature of lines, and is purely of a mathematical nature, after we have once ascertained by experiment, that light is bent in a certain way when it passes through transparent bodies. Now birds flying in the air, and meeting with many obstacles, as branches and leaves of trees, require to have their eyes sometimes as flat as possible for protection; but sometimes as round as possible, that they may see the small objects, flies and other insects, which they are chasing through the air, and which they pursue with the most unerring certainty. This could only be accomplished by giving them a power of suddenly changing the form of their eyes. Accordingly, there is a set of hard scales placed on the outer coat of their eye, round the place where the light enters; and over these scales are drawn the muscles or fibres by which motion is communicated; so that, by acting with these muscles, the bird can press the scales, and squeeze the natural magnifier of the eye into a round shape when it wishes to follow an insect through the air, and can relax the scales, in order to flatten the eye again when it would see a distant object, or move safely through leaves and twigs. This power of altering the shape of the eye is possessed by birds of prey in a very remarkable degree. They can see the smallest objects close to them, and can yet discern larger bodies at vast distances, as a carcass stretched upon the plain, or a dying fish afloat on the water.

A singular provision is made for keeping the surface of the bird's eye clean, for wiping the glass of the instrument, as it were, and also for protecting it, while rapidly flying through the air and through thickets, without hindering the sight. Birds are, for these purposes, furnished with a third eyelid, a fine membrane or skin, which is constantly moved

very rapidly over the eyeball by two muscles placed in the back of the eye. One of the muscles ends in a loop, the other in a string which goes through the loop, and is fixed in the corner of the membrane, to pull it backward and forward. If you wish to draw a thing towards any place with the least force, you must pull directly in the line between the thing and the place; but if you wish to draw it as quickly as possible, and do not regard the loss of force, you must pull it obliquely, by drawing it in two directions at once. Tie a string to a stone, and draw it straight towards you with one hand; then, make a loop on another string, and running the first through it, draw one string in each hand, not towards you, but sideways, till both strings are stretched in a straight line: you will see how much swifter the stone moves than it did before when pulled straight forward. Now this is proved, by mathematical reasoning, to be the necessary consequence of forces applied obliquely: there is a loss of power, but a great increase of velocity. The velocity is the thing required to be gained in the third eyelid, and the contrivance is exactly that of a string and a loop, moved each by a muscle, as the two strings are by the hands in the case we have been supposing.

A third eyelid of the same kind is found in the horse, and called the *haw;* it is moistened with a pulpy substance (or mucilage) to take hold of the dust on the eyeball, and wipe it clean off, so that the eye is hardly ever seen with any thing upon it, though greatly exposed from its size and posture. The swift motion of the haw is given to it by a gristly, elastic substance, placed between the eyeball and the socket, and striking obliquely, so as to drive out the haw with great velocity over the eye, and then let it come back as quickly. Ignorant persons when this haw is inflamed from cold and swells so as to appear, which it never does in a healthy state, often mistake it for an imperfection, and cut it off: So nearly does ignorance produce the same mischief as cruelty! They might as well cut off the pupil of the eye, taking it for a black spot.

If any quantity of matter, as a pound of wood or iron, is

fashioned into a rod of a certain length, say one foot, the rod will be strong in proportion to its thickness; and, if the figure is the same, that thickness can only be increased by making it hollow. Therefore, hollow rods or tubes, of the same length and quantity of matter, have more strength than solid ones. This is a principle so well understood now, that engineers make their axles and other parts of machinery hollow, and therefore stronger with the same weight, than they would be if thinner and solid. Now the bones of animals are all more or less hollow; and are therefore stronger with the same weight and quantity of matter than they otherwise would be. But birds have the largest bones in proportion to their weight; their bones are more hollow than those of animals which do not fly; and therefore they have strength without having to carry more weight than is absolutely necessary. Their quills derive strength from the same construction. They have another peculiarity to help their flight. No other animals have any communication between the air-vessels of their lungs and the hollow parts of their bodies; but birds have; and by this means they can blow out their bodies as we do a bladder, and thus make themselves lighter when they would either make their flight towards the ground slower, or rise more swiftly, or float more easily in the air. Fishes possess a power of the same kind, though not by the same means. They have air-bladders in their bodies, and can puff them out, or press them closer, at pleasure: when they want to rise in the water, they fill out the bladder, and this lightens them. If the bladder breaks, the fish remains at the bottom, and can only be held up by the most laborious exertions of the fins and tail. Accordingly, flat fish, as skates and flounders, which have no air-bladders, seldom rise from the bottom, but are found lying on banks in the sea, or at the bottom of sea rivers.

If you have a certain space, as a room, to build up with closets or little cells, all of the same size and shape, there are only three figures which will answer, and enable you to fill the room without losing any space between the cells; they must either be squares, or figures of three equal sides,

or figures of six equal sides. With any other figures whatever, space would be lost between the cells. This is evidently true upon considering the matter; and it is proved by mathematical reasoning. The six-sided figure is by far the most convenient of these three shapes, because its corners are flatter, and any round body placed in it has therefore more space, there being less room lost in the corners. Likewise, this figure is the strongest of the three; any pressure either from without or from within will hurt it less, as it has something of the strength of an arch. A round figure would be still stronger, but then room would be lost between the circles, whereas none at all is lost with the six-sided figure. Now, it is a most remarkable fact, that *Bees* build their cells exactly in this shape, and thereby save both room and materials beyond what they could save if they built in any other shape whatever. They build in the very best possible shape for their purpose, which is to save all the room and all the wax they can. So far as to the shape of the walls of each cell; but the roof and floor, or top and bottom, are built on equally true principles. It is proved by mathematicians, that to give the greatest strength and save the most room, the roof and floor must be made of three square planes meeting in a point; and they have further by a demonstration belonging to the highest parts of Algebra, that there is one particular angle or inclination of those planes to each other where they meet, which makes a greater saving of materials and of work than any other inclination whatever could possibly do. Now, the bees actually make the tops and bottoms of their cells of three planes meeting in a point, and the inclination or angle at which they meet is precisely the one found out by the mathematicians to be the best possible for saving wax and work. Who would dream for an instant of the bee knowing the highest branches of Mathematics—the fruits of Newton's most wonderful discovery—a result, too, of which he was himself ignorant, one of his most celebrated followers having found it out? This little insect works with a truth and correctness which are quite perfect, and according to the principles at which man has only arrived,

after ages of slow improvement in the most difficult branch of the most difficult science. But the mighty and all wise Creator, who made the insect and the philosopher, bestowing reason on the latter, and giving the former to work without it—to Him all truths are known from all eternity, with an intuition that mocks even the conceptions of the sagest of human kind.

It may be recollected, that when the air is exhausted or sucked out of any vessel, there is no longer the force necessary to resist the pressure of the air on the outside; and the sides of the vessel are therefore pressed inwards with violence: a flat glass would thus be broken, unless it were very thick; a round one, having the strength of an arch, would resist better; but any soft substance, as leather or skin, would be crushed or squeezed together at once. If the air was only sucked out slowly, the squeezing would be gradual, or, if it were only half sucked out, the skin would only be partly squeezed together. This is the very process by which *Bees* reach the fine dust and juices of hollow flowers, like the honeysuckle, and some kinds of long fox-glove, which are too narrow for them to enter. They fill up the mouth of the flower with their bodies, and suck out the air, or at least a large part of it; this makes the soft sides of the flower close, and squeezes the dust and juice towards the insect as well as a hand could do, if applied to the outside.

We may remember this pressure or weight of the atmosphere as shown by the barometer, the sucking-pump, and the air-pump. Its weight is near 15 pounds on every square inch, so that if we could entirely squeeze out the air between our two hands, they would cling together with a force equal to the pressure of double this weight, because the air would press upon both hands; and if we could contrive to suck or squeeze out the air between one hand and the wall, the hand would stick fast to the wall, being pressed on it with the weight of above two hundred weight, that is, near 15 pounds on every square inch of the hand. Now, by a late most curious discovery of Sir Everard Home, the distinguished anatomist, it is found that this is the very

process by which *Flies* and other insects of a similar description are enabled to walk up perpendicular surfaces, however smooth, as the sides of walls and panes of glass in windows, and to walk as easily along the ceiling of a room with their bodies downwards and their feet over head. Their feet, when examined by a microscope, are found to have flat skins or flaps, like the feet of web-footed animals, as ducks and geese; and they have towards the back part or heel, but inside the skin or flap, two very small toes so connected with the flap as to draw it close down upon the glass or wall the fly walks on, and to squeeze out the air completely, so that there is a vacuum made between the foot and the glass or wall. The consequence of this is, that the air presses the foot on the wall with a very considerable force compared to the weight of the fly; for if its feet are to its body in the same proportion as ours are to our bodies, since we could support by a single hand on the ceiling of the room (provided it made a vacuum) more than our whole weight, namely, a weight of fifteen stone, the fly can easily move on four feet in the same manner by help of the vacuum made under its feet. It has likewise been found that some of the larger sea animals are by the same construction, only upon a greater scale, enabled to climb the perpendicular and smooth surfaces of the ice hills among which they live. Some kinds of lizard have the same power of climbing, and of creeping with their bodies downwards along the ceiling of a room; and the means by which they are enabled to do so are the same. In the large feet of these animals, the contrivance is easily observed, of the two toes or tightners, by which the skin of the foot is pinned down, and the air excluded in the act of walking or climbing; but it is the very same, only upon a larger scale, with the mechanism of a fly's or butterfly's foot; and both operations, the climbing of the sea-horse on the ice, and the creeping of the fly on the window or the ceiling, are performed exactly by the same power, the weight of the atmosphere which causes the quicksilver to stand in the weather-glass, the wind to whistle through a key-hole, and the piston to descend in a steam-engine.

Although philosophers are not agreed as to the peculiar actions which light exerts upon vegetation, and there is even some doubt respecting the decomposition of air and water during that process, one thing is undeniable, the necessity of light to the growth and health of plants; and accordingly they are for the most part so formed as to receive it at all times when it shines on them. Their cups, and the little assemblages of their leaves before they sprout, are found to be more or less affected by the light, so as to open and receive it. In several kinds of plants this is more evident than in others; their flowers close entirely at night, and open in the day. Some constantly turn round towards the light, following the sun, as it were, while he makes or seems to make his revolution, so that they receive the greatest quantity possible of his rays. Thus clover in a field follows the apparent course of the sun. But all leaves of plants turn to the sun, place them how you will, light being essential to their thriving.

The lightness of inflammable gas is well known. When bladders, of any size, are filled with it, they rise upwards, and float in the air. Now, it is a most curious fact, ascertained by Mr. Knight, that the fine dust, by means of which plants are impregnated one from another, is composed of very small globules, filled with this gas—in a word, of small air balloons. These globules thus float from the male plant through the air, and striking against the females, are detained by a glue prepared on purpose to stop them, which no sooner moistens the globules than they explode, and their substance remains, the gas flying off which enabled them to float. A provision of a very simple kind is also, in some cases, made to prevent the male and female blossoms of the same plant from breeding together, this being found to hurt the breed of vegetables, just as breeding in and in does the breed of animals. It is contrived that the dust shall be shed by the male blossom before the female is ready to be affected by it, so that the impregnation must be performed by the dust of some other plant, and in this way the breed be crossed. The light gas with which the globules are filled is most

essential to this operation, as it conveys them to great distances. A plantation of yew trees has been known, in this way, to impregnate another several hundred yards off.

The contrivance by which some creeper plants are enabled to climb walls, and fix themselves, deserves attention. The *Virginia creeper* has a small tendril, ending in a claw, each toe of which has a knob, thickly set with extremely small bristles; they grow into the invisible pores of the wall, and swelling stick there as long as the plant grows, and prevent the branch from falling; but when the plant dies, they become thin again, and drop out, so that the branch falls down. The *Vanilla* plant of the West Indies climbs round trees likewise by means of tendrils; but when it has fixed itself, the tendrils drop off, and leaves are formed.

It is found by chemical experiments, that the juice which is in the stomachs of animals (called the *gastric* juice, from a Greek word signifying *the belly,*) has very peculiar properties. Though it is for the most part a tasteless, clear, and seemingly a very simple liquor, it nevertheless possesses extraordinary powers of dissolving substances which it touches or mixes with; and it varies in different classes of animals. In one particular it is the same in all animals: it will not attack living matter, but only dead; the consequence of which is, that its powers of eating away and dissolving are perfectly safe to the animals themselves, in whose stomachs it remains without ever hurting them. This juice differs in different animals according to the food on which they subsist: thus, in birds of prey, as kites, hawks, owls, it only acts upon animal matter, and does not dissolve vegetables. In other birds, and in all animals feeding on grass, as oxen, sheep, hares, it dissolves vegetable matter, as grass, but will not touch flesh of any kind. This has been ascertained by making them swallow balls with meat in them, and several holes drilled through, to let the gastric juice reach the meat: no effect was produced upon it. We may further observe, that there is a most curious and beautiful correspondence between this juice in the stomach of different animals and the other parts of

their bodies, connected with the important operations of eating and digesting their food. The use of the juice is plainly to convert what they eat into a fluid, from which, by various other processes, all their parts, blood, bones, muscles, &c. are afterwards formed. But the food is first of all to be obtained, and then prepared by bruising, for the action of the juice. Now birds of prey have instruments, their claws and beak, for tearing and devouring their food, (that is animals of different kinds,) but those instruments are useless for picking up and crushing seeds: accordingly, they have a gastric juice which dissolves the animals they eat; while birds which have only a beak fit for pecking, drinking, and eating seeds, have a juice that dissolves seeds, and not flesh. Nay more, it is found that the seeds must be bruised before the juice will dissolve them: this you find by trying the experiment in a vessel with the juice; and accordingly the birds have a gizzard, and animals which graze have flat teeth, which grind and bruise their food before the gastric juice is to act upon it.

We have seen how wonderfully the *Bee* works, according to rules discovered by man thousands of years after the insect had followed them with perfect accuracy. The same little animal seems to be acquainted with principles of which we are still ignorant. We can, by crossing vary the forms of cattle with astonishing nicety; but we have no means of altering the nature of an animal once born, by means of treatment and feeding. This power, however, is undeniably possessed by the bees. When the queen bee is lost, by death or otherwise, they choose a grub from among those which are born for workers; they make three cells into one, and placing the grub there, they build a tube round it; they afterwards build another cell of a pyramidal form, into which the grub grows: they feed it with peculiar food, and tend it with extreme care. It becomes, when transformed from the worm to the fly, not a worker, but a queen bee.

These singular insects resemble our own species, in one of our worst propensities, the disposition to war; but their attention to their sovereign is equally extraordinary, though

of a somewhat capricious kind. In a few hours after their queen is lost, the whole hive is in a state of confusion. A singular humming is heard, and the bees are seen moving all over the surface of the combs with great rapidity. The news spread quickly, and when the queen is restored, quiet immediately succeeds. But if another queen is put upon them, they instantly discover the trick, and, surrounding her, they either suffocate or starve her to death. This happens if the false queen is introduced within a few hours after the first is lost or removed; but if twenty-four hours have elapsed, they will receive any queen, and obey her.

The labours and the policy of the *Ants* are, when closely examined, still more wonderful, perhaps than those of the *Bee*. Their nest is a city consisting of dwelling-places, halls, streets, and squares, into which the streets open. The food they principally like is the honey which comes from another insect found in their neighbourhood, and which they, generally speaking, bring home from day to day as they want it. Later discoveries have shown that they do not eat grain, but live almost entirely on animal food and this honey. Some kinds of ant have the foresight to bring home the insects on whose honey they feed, and keep them in particular cells, where they guard them to prevent their escaping, and feed them with proper vegetable matter which they do not eat themselves. Nay, they obtain the eggs of those insects, and superintend their hatching, and then rear the young insect until he becomes capable of supplying the desired honey. They sometimes remove them to the strongest parts of their nest, where there are cells apparently fortified for protecting them from invasion. In those cells the insects are kept to supply the wants of the whole ants which compose the population of the city. It is a most singular circumstance in the economy of nature, that the degree of cold at which the ant becomes torpid is also that at which this insect falls into the same state. It is considerably below the freezing point; so that they require food the greater part of the winter, and if the insects on which they depend for food were not kept alive

16 *

during the cold in which the ants can move about, the latter would be without the means of subsistence.

How trifling soever this little animal may appear in our climate, there are few more formidable creatures than the ant of some tropical countries. A traveller who lately filled a high station in the French government, Mr. Malouet, has described one of their cities, and, were not the account confirmed by various testimonies, it might seem exaggerated. He observed at a great distance what seemed a lofty structure, and was informed by his guide that it consisted of an ant hill, which could not be approached without danger of being devoured. Its height was from 15 to 20 feet, and its base 30 or 40 feet square. Its sides inclined like the lower part of a pyramid, the point being cut off. He was informed that it became necessary to destroy these nests, by raising a sufficient force to dig a trench all round, and fill it with fagots, which were afterwards set on fire; and then battering with cannon from a distance, to drive the insects out and make them run into the flames. This was in South America; and African travellers have met with them in the same formidable numbers and strength.

The old writers of books upon the habits of some animals abound with stories which may be of doubtful credit. But the facts now stated respecting the Ant and Bee, may be relied on as authentic. They are the result of very late observations, and experiments made with great accuracy by several most worthy and intelligent men, and the greater part of them have the confirmation arising from more than one observer having assisted in the inquiries. The habits of *Beavers* are equally well authenticated, and, being more easily observed, are vouched by a greater number of witnesses. These animals, as if to enable them to live and move either on land or water, have two web feet like those of ducks or water dogs, and two like those of land animals. When they wish to construct a dwelling-place, or rather city, for it serves the whole body, they choose a level place with a stream running through it; they dam up the stream so as to make a pond, and per-

form the operation as skilfully as we could ourselves. They drive into the ground stakes of five or six feet long in rows, wattling each row with twigs, and puddling or filling the interstices with clay which they ram close in, so as to make the whole solid and water-tight. This dam is likewise shaped on the truest principles;* for the upper side next the water slopes, and the side below is perpendicular; the base of the dam is 10 or 12 feet thick: the top or narrow part two or three, and it is sometimes as long as 100 feet. The pond being thus formed and secured, they make their houses round the edge of it; they are cells, with vaulted roofs, and upon piles; they are made of stones, earth, and sticks; the walls are two feet thick, and plastered as neatly as if the trowel had been used. Sometimes they have two or three stories for retreating to in case of floods, and they always have two doors, one towards the water, and one towards the land. They keep their winter provisions in stores, and bring them out to use; they make their beds of moss; they live on the bark of trees, gums, and crawfish. Each house holds from twenty to thirty, and there may be from ten to twenty-five houses in all. Some of their communities are therefore larger than others, but there are seldom fewer than two or three hundred inhabitants. In working they all bear their shares: some gnaw the trees and branches with their teeth to form stakes and beams; others roll the pieces to the water; others diving make holes with their

* If the base is 12, and the top 3 feet thick, and the height 6 feet, the face must be the side of a right-angled triangle, whose height is 8 feet. This would be the exact proportion which there ought to be, upon mathematical principles, to give the greatest resistance possible to the water in its tendency to turn the dam round, provided the materials of which it is made were lighter than water in the proportion of 44 to 100. But the materials are probably more than twice as heavy as water, and the form of so flat a dike is taken, in all likelihood, in order to guard against a more imminent danger,—that of the dam being carried away by being shoved forwards. We cannot calculate what the proportions are which give the greatest possible resistance to this tendency, without knowing the tenacity of the materials, as well as their specific gravity. It may very probably be found that the construction is such as to secure the most completely against the two pressures at the same time.

teeth to place the piles in; others collect and carry stones and clay; others beat and mix the mortar; and others carry it on their broad tails, and with these beat it and plaster it. Some superintend the rest, and make signals by sharp strokes with the tail, which are carefully attended to; the beavers hastening to the place where they are wanted to work, or to repair any hole made by the water, or to defend themselves or make their escape, when attacked by an enemy.

The fitness of different animals, by their bodily structure, to the circumstances in which they are found, presents an endless subject of curious inquiry and pleasing contemplation. Thus, the *Camel* which lives in sandy deserts has broad spreading hoofs to support him on the loose soil; and an apparatus in his body by which water is kept for many days, to be used when no moisture can be had. As this would be useless in the neighborhood of streams or wells, and as it would be equally so in the desert, where no water is to be found, there can be no doubt that it is intended to assist in journeying across the sands from one watered spot to another. There is a singular and beautiful provision made in this animal's foot, for enabling it to sustain the fatigues of journeys under the pressure of its great weight. Beside the yielding of the bones and ligaments, or bindings, which gives elasticity to the foot of the deer and other animals, there is in the camel's foot, between the horny sole and the bones, a cushion, like a ball, of soft matter, almost fluid, but in which there is a mass of threads extremely elastic, interwoven with the pulpy substance. The cushion thus easily changes its shape when pressed, yet it has such an elastic spring, that the bones of the foot press on it uninjured by the heavy body which they support, and this huge animal steps as softly as a cat.

Nor need we flee to the desert in order to witness an example of skilful structure in the foot: the *Horse's* limbs display it strikingly. The bones of the foot are not placed directly under the weight; if they were in an upright position, they would make a firm pillar, and every motion

would cause a shock. They are placed slanting or oblique, and tied together by an elastic binding on their lower surfaces, so as to form springs as exact as those which we make of leather or steel for carriages. Then the flatness of the hoof which stretches out on each side, and the frog coming down in the middle between the quarters, adds greatly to the elasticity of the machine. Ignorant of this, ill-informed farriers nail the shoe too far back, fixing the quarters, and causing permanent contraction—so that the contracted hoof loses its elasticity; every step is a shock; inflammation and lameness ensue.

The *Rein-deer* inhabits a country covered with snow the greater part of the year. Observe how admirably its hoof is formed for going over that cold and light substance, without sinking in it, or being frozen. The under side is covered entirely with hair, of a warm and close texture; and the hoof, altogether, is very broad, acting exactly like the snow-shoes which men have constructed for giving them a larger space to stand on than their feet, and thus to avoid sinking. Moreover, the deer spreads the hoof as wide as possible when it touches the ground; but, as this breadth would be inconvenient in the air, by occasioning a greater resistance while he is moving along, no sooner does he lift the hoof than the two parts into which it is cloven fall together, and so lessen the surface exposed to the air, just as we may recollect the birds doing with their bodies and wings. The shape and structure of the hoof is also well adapted to scrape away the snow, and enable the animal to get at the particular kind of moss (or *lichen*) on which he feeds. This plant, unlike others, is in its full growth during the winter season; and the rein-deer, accordingly, thrives from its abundance, notwithstanding the unfavourable effects of extreme cold upon the animal system.

There are some insects, of which the males have wings, and the females are grubs or worms. Of these, the *Glow-worm* is the most remarkable: it is the female, and the male is a fly, which would be unable to find her out, creep-

ing, as she does, in the dark lanes, but for the shining light which she gives, to attract him.

There is a singular fish found in the Mediterranean, called the *Nautilus*, from its skill in navigation. The back of its shell resembles the hulk of a ship; on this it throws itself, and spreads a thin membrane to serve for a sail, paddling itself on with its feet as oars.

The *Ostrich* lays and hatches her eggs in the sands; her form being ill adapted to that process, she has a natural oven furnished by the sand, and the strong heat of the sun. The *Cuckoo* is known to build no nest for herself, but to lay in the nests of other birds; but late observations show that she does not lay indiscriminately in the nests of all birds; she only chooses the nests of those which have bills of the same kind with herself, and therefore feed on the same kind of food. The *Duck*, and other birds breeding in muddy places, have a peculiar formation of the bill: it is both made so as to act like a strainer, separating the finer from the grosser parts of the liquid, and it is more furnished with nerves near the point than the bills of birds which feed on substances exposed to the light; so that it serves better to grope in the dark stream for food, being more sensitive. The bill of the *Snipe* is covered with a curious net-work of nerves for the same purpose; but a bird, (the *Toucan* or *Egg-sucker*,) which chiefly feeds on the eggs found in birds' nests, and in countries where these are very deep and dark, has the most singular provision of this kind. Its bill is very broad and long; when examined, it is completely covered with branches of nerves in all directions; so that, by groping in a deep and dark nest, it can feel its way as accurately as the finest and most delicate finger could. Almost all kinds of birds build their nests of materials found where they inhabit, or use the nests of other birds; but the *Swallow of Java* lives in rocky caverns on the sea, where there are no materials at all for the purpose of building. It is therefore so formed as to secrete in its body a kind of slime with which it makes a nest, much prized as a delicate food in eastern countries.

Plants, in many remarkable instances, are provided for

by equally wonderful and skilful contrivances. There is one, the *Muscipula*, *Fly-trap*, or *Fly-catcher*, which has small prickles in the inside of two leaves, or half leaves, joined by a hinge; a juice or syrup is provided on their inner surface, and acts as a bait to allure flies. There are several small spines or prickles standing upright in this syrup, and upon the only part of each leaf that is sensitive to the touch. When the fly therefore settles upon this part, its touching as it were the spring of the trap occasions the leaves to shut and kill and squeeze the insect; so that its juices and the air arising from their rotting serve as food to the plant.

In the West Indies, and other hot countries, where rain sometimes does not fall for a great length of time, a kind of plant called the *Wild-pine* grows upon the branches of the trees, and also on the bark of the trunk. It has hollow or bag-like leaves so formed as to make little reservoirs of water, the rain falling into them through channels which close at the top when full, to prevent it from evaporating. The seed of this useful plant has small floating threads, by which, when carried through the air, it catches any tree in the way, and falls on it and grows. Wherever it takes root, though on the under side of a bough, it grows straight upwards, otherwise the leaves would not hold water. It holds in one leaf from a pint to a quart; and although it must be of great use to the trees it grows on, to birds and other animals its use is even greater. Another tree, called the *Water-with*, in Jamaica, has similar uses; it is like a vine in size and shape, but growing in very parched districts, is yet so full of clear sap or water, that on cutting a piece two or three yards long, and merely holding it to the mouth, a plentiful draught is obtained. In the East there is a plant somewhat of the same kind, called the *Bejuco*, which grows near other trees and twines round them, with its end hanging downwards, but so full of juice, that on cutting it, a plentiful stream of water spouts from it; and this, not only by its touching the tree so closely must refresh it, but is a supply to animals, and to the weary herdsman on the mountains.

V. After the many instances or samples which have now been given of the nature and objects of Natural Science, we might proceed to a different field, and describe in the same way the other grand branch of Human Knowledge, that which teaches the properties or habits of *Mind*—the *intellectual faculties* of man; that is to say, the powers of his understanding, by which he perceives, imagines, remembers, and reasons;—his *moral faculties*, that is to say, the feelings and passions which influence him;—and, lastly, as a conclusion or result drawn from the whole, his *duties* both towards himself as an individual, and towards others as a member of society; which last head opens to our view the whole doctrines of *political science*, including the nature of governments, of policy, and generally of laws. But we shall abstain at present from entering at all upon this field, and shall now take up the subject, more particularly pointed at through the course of the preceding observations, and to illustrate which they have been framed, namely,—the use and importance of scientific studies.

Man is composed of two parts, body and mind, connected indeed together, but wholly different from one another. The nature of the union—the part of our outward and visible frame in which it is peculiarly formed—or whether the soul be indeed connected with any particular portion of the body, so as to reside there—are points as yet wholly hid from our knowledge, and which are likely to remain for ever concealed. But this we know, as certainly as we can know any truth, that there is such a thing as the mind; and that we have at the least as good proof of its existence, independent of the body, as we have of the existence of the body itself. Each has its uses, and each has its peculiar gratifications. The bounty of Providence has given us outward senses to be employed, and has furnished the means of gratifying them in various kinds, and in ample measure. As long as we only taste those pleasures according to the rules of prudence and of our duty, that is in moderation for our own sakes, and in harmlessness towards our neighbours, we fulfil rather than thwart the purposes of our being. But the same bountiful Providence

has endowed us with the higher nature also—with understandings as well as with senses—with faculties that are of a more exalted nature, and admit of more refined enjoyments, than any the bodily frame can bestow; and by pursuing such gratifications rather than those of mere sense, we fulfil the highest ends of our creation, and obtain both a present and a future reward. These things are often said, but they are not therefore the less true, or the less worthy of deep attention. Let us mark their practical application to the occupations and enjoyments of all branches of society, beginning with those who form the great bulk of every community, the working classes, by what names soever their vocations may be called—professions, arts, trades, handicrafts, or common labour.

The first object of every man who has to depend upon his own exertions must needs be to provide for his daily wants. This is a high and important office; it deserves his utmost attention; it includes some of his most important duties, both to himself, his kindred, and his country; and although in performing this office, he is only influenced by his own interest, or by his necessities, yet it is one which renders him truly the best benefactor of the community to which he belongs. All other pursuits must give way to this; the hours which he gives to learning must be after he has done his work; his independence, without which he is not worthy to be called a man, requires first of all that he should have ensured for himself, and those dependent on him, a comfortable subsistence before he can have a right to taste any indulgence, either of his senses or of his mind; and the more he learns—the greater progress he makes in the sciences—the more will he value that independence, and the more will he prize the industry, the habits of regular labour, whereby he is enabled to secure so prime a blessing.

In one view, it is true, the progress which he makes in science may help his ordinary exertions, the main business of every man's life. There is hardly any trade or occupation in which useful lessons may not be learnt by studying one science or another. The necessity of science to the

more liberal professions is self-evident; little less manifest is the use to their members of extending their knowledge beyond the branches of study, with which their several pursuits are more peculiarly conversant. But the other departments of industry derive hardly less benefit from the same source. To how many kinds of workmen must a knowledge of Mechanical Philosophy prove useful! To how many others does Chemistry prove almost necessary! Every one must with a glance perceive that to engineers, watch-makers, instrument-makers, bleachers, and dyers, those sciences are most useful, if not necessary. But carpenters and masons are surely likely to do their work better for knowing how to measure, which Practical Mathematics teaches them, and how to estimate the strength of timber, of walls, and of arches, which they learn from Practical Mechanics; and they who work in various metals are certain to be the more skilful in their trades for knowing the nature of those substances, and their relations to both heat and other metals, and to the airs and liquids they come in contact with. Nay, the farm-servant, or day-labourer, whether in his master's employ, or tending the concerns of his own cottage, must derive great practical benefit,—must be both a better servant, and a more thrifty and therefore comfortable, cottager, for knowing something of the nature of soils and manures, which Chemistry teaches, and something of the habits of animals, and the qualities and growth of plants, which he learns from Natural History and Chemistry together. In truth, though a man be neither mechanic nor peasant, but only one having a pot to boil, he is sure to learn from science lessons which will enable him to cook his morsel better, save his fuel, and both vary his dish and improve it. The art of good and cheap cookery is intimately connected with the principles of chemical philosophy, and has received much, and will yet receive more, improvement from their application. Nor is it enough to say, that philosophers may discover all that is wanted, and may invent practical methods, which it is sufficient for the working man to learn by rote without knowing the principles. He never will work so well if he

is ignorant of the principles; and for a plain reason:—if he only learn his lesson by rote, the least change of circumstances puts him out. Be the method ever so general, cases will always arise in which it must be varied in order to apply; and if the workman only knows the rule without knowing the reason, he must be at fault the moment he is required to make any new application of it. This, then, is the *first* use of learning the principles of science: it makes men more skilful, expert, and useful in the particular kinds of work by which they are to earn their bread, and by which they are to make it go far and taste well when earned.

But another use of such knowledge to handicraftsmen and common labourers is equally obvious: it gives every man a chance, according to his natural talents, of becoming an improver of the art he works at, and even a discoverer in the sciences connected with it. He is daily handling the tools and materials with which new experiments are to be made; and daily witnessing the operations of nature, whether in the motions and pressures of bodies, or in their chemical actions on each other. All opportunities of making experiments must be unimproved, all appearances must pass unobserved, if he has no knowledge of the principles; but with this knowledge he is more likely than another person to strike out something new which may be useful in art, or curious or interesting in science. Very few great discoveries have been made by chance and by ignorant persons—much fewer than is generally supposed. It is commonly told of the steam-engine that an idle boy being employed to stop and open a valve, saw that he could save himself the trouble of attending and watching it, by fixing a plug upon a part of the machine which came to the place at the proper times, in consequence of the general movement. This is possible, no doubt; though nothing very certain is known respecting the origin of the story; but improvements of any value are very seldom indeed so easily found out, and hardly another instance can be named of important discoveries so purely accidental. They are generally made by persons of competent knowledge, and who are in

search of them. The improvements of the steam-engine by Watt resulted from the most learned investigation of mathematical, mechanical, and chemical truths. Arkwright devoted many years, five at the least, to his invention of Spinning jennies, and he was a man perfectly conversant in every thing that relates to the construction of machinery: he had minutely examined it, and knew the effects of each part, though he had not received any thing like a scientific education. If he had, we should in all probability have been indebted to him for scientific discoveries as well as practical improvements. The most beautiful and useful invention of late times, the Safety-lamp, was the reward of a series of philosophical experiments made by one thoroughly skilled in every branch of chemical science. The new process of Refining sugar, by which more money has been made in a shorter time, and with less risk and trouble, than was ever perhaps gained from an invention, was discovered by a most accomplished chemist,* and was the fruit of a long course of experiments, in the progress of which, known philosophical principles were constantly applied, and one or two new principles ascertained. But in so far as chance has any thing to do with discovery, surely it is worth the while of those who are constantly working in particular employments to obtain the knowledge required, because their chances are greater than other people's of so applying that knowledge as to hit upon new and useful ideas: they are always in the way of perceiving what is wanting, or what is amiss in the old methods; and they have a better chance of making the improvements. In a word, to use a common expression, they are in the way of good luck; and if they possess the requisite information, they can take advantage of it when it comes to them. This, then, is the *second* great use of learning the sciences: it enables men to make improvements in the arts, and discoveries in philosophy, which may directly benefit themselves and mankind.

Now, these are the *practical* advantages of learning;

* Edward Howard, brother of the Duke of Norfolk.

but the *third* benefit is, when rightly considered, just as practical as the other two—the pleasure derived from mere knowledge, without any view to our own bodily enjoyments; and this applies to all classes, the idle as well as the industrious, if, indeed, it be not peculiarly applicable to those who have the inestimable blessing of time at their command. Every man is by nature endowed with the power of gaining knowledge, and the taste for it: the capacity to be pleased with it forms equally a part of the natural constitution of his mind. It is his own fault, or the fault of his education, if he derives no gratification from it. There is a satisfaction in knowing what others know—in not being more ignorant than those we live with: there is a satisfaction in knowing what others do not know—in being more informed than they are. But this is quite independent of the pure pleasure of knowledge—of gratifying a curiosity implanted in us by Providence, to lead us towards the better understanding of the universe in which our lot is cast, and the nature wherewithal we are clothed. That every man is capable of being delighted with extending his information upon matters of science will be evident from a few plain considerations.

Reflect how many parts of the reading, even of persons ignorant of all sciences, refer to matters wholly unconnected with any interest or advantage to be derived from the knowledge acquired. Every one is amused with reading a story: a romance may please some, and a fairy tale may entertain others; but no benefit beyond the amusement is derived from this source: the imagination is gratified; and we willingly spend a good deal of time and a little money in this gratification, rather than in rest after fatigue, or in any other bodily indulgence. So we read a newspaper, without any view to the advantage we are to gain from learning the news, but because it interests and amuses us to know what is passing. One object, no doubt, is to become acquainted with matters relating to the welfare of the country; but we read the occurrences which do little or not at all regard the public interests, and we take a pleasure in reading them. Accidents, adventures,

anecdotes, crimes, and a variety of other things amuse us, independent of the information respecting public affairs, in which we feel interested as citizens of the state, or as members of a particular body. It is of little importance to inquire how and why these things excite our attention, and wherefore the reading about them is a pleasure: the fact is certain; and it proves clearly that there is a positive enjoyment in knowing what we did not know before; and this pleasure is greatly increased when the information is such as excites our surprise, wonder, or admiration. Most persons who take delight in reading tales of ghosts, which they know to be false, and feel all the while to be silly in the extreme, are merely gratified, or rather occupied, with the strong emotions of horror excited by the momentary belief, for it can only last an instant. Such reading is a degrading waste of precious time, and has even a bad effect upon the feelings and the judgment. But true stories of horrid crimes, as murders, and pitiable misfortunes, as shipwrecks, are not much more instructive. It may be better to read these than to sit yawning and idle—much better than to sit drinking or gaming, which, when carried to the least excess, are crimes in themselves, and the fruitful parents of many more. But this is nearly as much as can be said for such vain and unprofitable reading. If it be a pleasure to gratify curiosity, to know what we were ignorant of, to have our feelings of wonder called forth, how pure a delight of this very kind does Natural Science hold out to its students? Recollect some of the extraordinary discoveries of Mechanical Philosophy. How wonderful are the laws that regulate the motions of fluids! Is there any thing in all the idle books of tales and horrors more truly astonishing than the fact, that a few pounds of water may, by mere pressure, without any machinery, by merely being placed in a particular way, produce an irresistible force? What can be more strange, than that an ounce weight should balance hundreds of pounds, by the intervention of a few bars of thin iron? Observe the extraordinary truths which Optical Science discloses. Can any thing surprise us more, than to find that the colour of white

is a mixture of all others—that red, and blue, and green, and all the rest, merely by being blended in certain proportions, form what we had fancied rather to be no colour at all, than all colours together? Chemistry is not behind in its wonders. That the diamond should be made of the same material with coal; that water should be chiefly composed of an inflammable substance; that acids should be almost all formed of different kinds of air, and that one of those acids, whose strength can dissolve almost any of the metals, should be made of the self-same ingredients with the common air we breathe; that salts should be of a metallic nature and composed, in great part, of metals, fluid like quicksilver, but lighter than water, and which, without any heating, take fire upon being exposed to the air, and, by burning, form the substance so abounding in saltpetre and in the ashes of burnt wood: these, surely, are things to excite the wonder of any reflecting mind—nay, of any one but little accustomed to reflect. And yet these are trifling when compared to the prodigies which Astronomy opens to our view: the enormous masses of the heavenly bodies; their immense distances; their countless numbers, and their motions, whose swiftness mocks the uttermost efforts of the imagination.

Akin to this pleasure of contemplating new and extraordinary truths, is the gratification of a more learned curiosity, by tracing resemblances and relations between things, which, to common apprehension, seem widely different. Mathematical science to thinking minds affords this pleasure in a high degree. It is agreeable to know that the three angles of every triangle, whatever be its size, howsoever its sides may be inclined to each other, are always of necessity, when taken together, the same in amount: that any regular kind of figure whatever, upon the one side of a right-angled triangle, is equal to the two figures of the same kind upon the two other sides, whatever be the size of the triangle: that the properties of an oval curve are extremely similar to those of a curve, which appears the least like it of any, consisting of two branches of infinite extent, with their backs turned to each other. To trace

such unexpected resemblances is, indeed, the object of all philosophy; and experimental science in particular is occupied with such investigations, giving us general views, and enabling us to explain the appearances of nature, that is, to show how one appearance is connected with another. But we are now only considering the gratification derived from learning these things. It is surely a satisfaction, for instance, to know that the same thing, or motion, or whatever it is, which causes the sensation of heat, causes also fluidity, and expands bodies in all directions; that electricity, the light which is seen on the back of a cat when slightly rubbed on a frosty evening, is the very same matter with the lightning of the clouds;—that plants breathe like ourselves, but differently by day and by night;—that the air which burns in our lamps enables a balloon to mount, and causes the globules of the dust of plants to rise, float through the air, and continue their race;—in a word, is the immediate cause of vegetation. Nothing can at first view appear less like, or less likely to be caused by the same thing, than the processes of burning and of breathing,—the rust of metals and burning,—an acid and rust,—the influence of a plant on the air it grows in by night, and of an animal on the same air at any time, nay, and of a body burning in that air; and yet all these are the same operation. It is an undeniable fact, that the very same thing which makes the fire burn, makes metals rust, forms acids, and causes plants and animals to breathe; that these operations, so unlike to common eyes, when examined by the light of science, are the same,—the rusting of metals,—the formation of acids,—the burning of inflammable bodies,—the breathing of animals,—and the growth of plants by night. To know this is a positive gratification. Is it not pleasing to find the same substance in various situations extremely unlike each other;—to meet with fixed air as the produce of burning,—of breathing,—and of vegetation;—to find that it is the choak-damp of mines,—the bad air in the grotto at Naples,—the cause of death in neglected brewers' vats,—and of the brisk and acid flavour of Seltzer and other mineral springs? Nothing can be less like than

the working of a vast steam-engine, and the crawling of a fly upon the window. We find that these two operations are performed by the same means, the weight of the atmosphere, and that a sea-horse climbs the ice-hills by no other power. Can any thing be more strange to contemplate? Is there in all the fairy tales that ever were fancied, any thing more calculated to arrest the attention and to occupy and to gratify the mind, than this most unexpected resemblance between things so unlike to the eyes of ordinary beholders? What more pleasing occupation than to see uncovered and bared before our eyes the very instrument and the process by which nature works? Then we raise our views to the structure of the heavens; and are again gratified with tracing accurate but most unexpected resemblances. Is it not in the highest degree interesting to find, that the power which keeps this earth in its shape, and in its path, wheeling round the sun, extends over all the other worlds that compose the universe, and gives to each its proper place and motion; that this same power keeps the moon in her path round our earth, and our earth in its path round the sun, and each planet in its path; that the same power causes the tides upon our earth, and the peculiar form of the earth itself; and that, after all, it is the same power which makes a stone fall to the ground? To learn these things, and to reflect upon them, fills the mind, and produces certain as well as pure gratification.

But if the knowledge of the doctrines unfolded by science is pleasing, so is the being able to trace the steps by which those doctrines are investigated, and their truth demonstrated: indeed you cannot be said, in any sense of the word, to have learnt them, or to know them, if you have not so studied them as to perceive how they are proved. Without this you never can expect to remember them long, or to understand them accurately; and that would of itself be reason enough for examining closely the grounds they rest on. But there is the highest gratification of all, in being able to see distinctly those grounds, so as to be satisfied that a belief in the doctrines is well founded. Hence to follow a demonstration of a grand

mathematical truth—to perceive how clearly and how inevitably one step succeeds another, and how the whole steps lead to the conclusion—to observe how certainly and unerringly the reasoning goes on from things perfectly self-evident, and by the smallest addition at each step, every one being as easily taken after the one before, as the first step of all was, and yet the result being something not only far from self-evident, but so general and strange, that you can hardly believe it to be true, and are only convinced of it by going over the whole reasoning—this operation of the understanding, to those who so exercise themselves, always affords the highest delight. The contemplation of experimental inquiries, and the examination of reasoning founded upon the facts which our experiments and observations disclose, is another fruitful source of enjoyment, and no other means can be devised for either imprinting the results upon our memory, or enabling us really to enjoy the whole pleasures of science. They who found the study of some branches dry and tedious at the first, have generally become more and more interested as they went on; each difficulty overcome gives an additional relish to the pursuit, and makes us feel, as it were, that we have by our work and labour established a right of property in the subject. Let any man pass an evening in listless idleness, or even in reading some silly tale, and compare the state of his mind when he goes to sleep or gets up next morning with its state some other day when he has passed a few hours in going through the proofs, by facts and reasoning, of some of the great doctrines in Natural Science, learning truths wholly new to him, and satisfying himself by careful examination of the grounds on which known truths rest, so as to be not only acquainted with the doctrines themselves, but able to show why he believes them, and to prove before others that they are true—he will find as great a difference as can exist in the same being; the difference between looking back upon time unprofitably wasted, and time spent in self-improvement: he will feel himself in the one case listless and dissatisfied, in the other comfortable and happy; in the one case, if he do not appear to him-

self humbled, at least he will not have earned any claim to his own respect; in the other case, he will enjoy a proud consciousness of having, by his own exertion, become a wiser and therefore a more exalted creature.

To pass our time in the study of the sciences, in learning what others have discovered, and in extending the bounds of human knowledge, has, in all ages, been reckoned the most dignified and happy of human occupations; and the name of Philosopher, or Lover of Wisdom, is given to those who lead such a life. But it is by no means necessary that a man should do nothing else than study known truths, and explore new, in order to earn this high title. Some of the greatest philosophers, in all ages, have been engaged in the pursuits of active life; and an assiduous devotion of the bulk of our time to the work which our condition requires, is an important duty, and indicates the possession of practical wisdom. This, however, does by no means hinder us from applying the rest of our time, beside what nature requires for meals and rest, to the study of science; and he who, in whatever station his lot may be cast, works his day's work, and improves his mind in the evening, as well as he who, placed above such necessity, prefers the refined and elevating pleasures of knowledge to the low gratification of the senses, richly deserves the name of a True Philosopher.

One of the most gratifying treats which science affords us is the knowledge of the extraordinary powers with which the human mind is endowed. No man, until he has studied philosophy, can have a just idea of the great things for which Providence has fitted his understanding, the extraordinary disproportion which there is between his natural strength and the powers of his mind, and the force which he derives from those powers. When we survey the marvellous truths of Astronomy, we are first of all lost in the feeling of immense space, and of the comparative insignificance of this globe and its inhabitants. But there soon arises a sense of gratification and of new wonder at perceiving how so insignificant a creature has been able to reach such a knowledge of the unbounded system of the

universe—to penetrate, as it were, through all space, and become familiar with the laws of nature at distances so enormous as baffle our imagination—to be able to say, not merely that the Sun has 329,630 times the quantity of matter which our globe has, Jupiter $308\frac{9}{10}$, and Saturn $93\frac{1}{2}$ times; but that a pound of lead weighs at the Sun 22 lbs. 15 ozs. 16 dwts. 8 grs. and $\frac{3}{4}$ of a grain; at Jupiter 2 lbs. 1 oz. 19 dwt. 1 gr. $\frac{29}{43}$; and at Saturn 1 lb. 3 ozs. 8 dwts. 20 grs. $\frac{1}{11}$ part of a grain; and what is far more wonderful, to discover the laws by which the whole of this vast system is held together, and maintained through countless ages in perfect security and order. It is surely no mean reward of our labour to become acquainted with the prodigious genius of those who have almost exalted the nature of man above its destined sphere; and, admitted to a fellowship with those loftier minds, to know how it comes to pass that by universal consent they hold a station apart, rising over all the Great Teachers of mankind, and spoken of reverently, as if NEWTON and LAPLACE were not the names of mortal men.

The highest of all our gratifications in the contemplations of science remains: we are raised by them to an understanding of the infinite wisdom and goodness which the Creator has displayed in all his works. Not a step can we take in any direction without perceiving the most extraordinary traces of design; and the skill every where conspicuous is calculated in so vast a proportion of instances to promote the happiness of living creatures, and especially of ourselves, that we can feel no hesitation in concluding, that if we knew the whole scheme of Providence, every part would be in harmony with a plan of absolute benevolence. Independently, however, of this most consoling inference, the delight is inexpressible of being able to follow, as it were, with our eyes, the marvellous works of the Great Architect of Nature, to trace the unbounded power and exquisite skill which are exhibited in the most minute, as well as the mightiest parts of his system. The pleasure derived from this study is unceasing, and so various, that it never tires the appetite. But it is unlike the

low gratifications of sense in another respect: it elevates and refines our nature, while those hurt the health, debase the understanding, and corrupt the feelings; it teaches us to look upon all earthly objects as insignificant, and below our notice, except the pursuit of knowledge and the cultivation of virtue—that is to say, the strict performance of our duty in every relation of society; and it gives a dignity and importance to the enjoyment of life, which the frivolous and the grovelling cannot even comprehend.

Let us, then, conclude, that the Pleasures of Science go hand in hand with the solid benefits derived from it; that they tend, unlike other gratifications, not only to make our lives more agreeable, but better; and that a rational being is bound by every motive of interest and of duty, to direct his mind towards pursuits which are found to be the sure path of virtue as well as of happiness.

AN ACCOUNT

OF

LORD BACON'S

NOVUM ORGANON SCIENTIARUM,

OR

NEW METHOD OF STUDYING THE SCIENCES.

THE FIRST OR INTRODUCTORY PART.

FROM THE BRITISH LIBRARY OF USEFUL KNOWLEDGE.

HOMO, NATURÆ MINISTER ET INTERPRES, TANTUM FACIT ET INTELLIGIT QUANTUM DE NATURÆ ORDINE RE VEL MENTE OBSERVAVERIT; NEC AMPLIUS SCIT, AUT POTEST..........*Nov. Org.*

LORD BAÇON was the first who taught the proper method of studying the sciences; that is, he pointed out the way in which we should begin and carry on our pursuit of knowledge, in order to arrive at *truth*. He gave a set of rules by which mankind might deliver themselves from slavery to names, and from wandering among fanciful systems, and return once more, as little children, to the school of nature. The task he chose was far more useful to the world, and honorable to himself, than that of being, like Plato or Aristotle, the author of a new sect: he undertook to expose the errors of those who had gone before him, and to show the best way of avoiding them for the future: he had the principal share in pulling down the old building of a false

philosophy, and, with the skill of a superior architect, he laid the foundation and sketched the plan of another fabric; and gave masterly directions to those who should come after him—how, upon the ruins of the first, the temple of science must be erected anew. As, in a great army, there are some whose office it is to construct bridges, to cut paths along mountains, and to remove various impediments, so Lord Bacon may be said to have cleared the way to knowledge; to have marked out the road to truth; and to have left future travellers little else to do, than follow his instructions: he was the miner and sapper of philosophy, the pioneer of nature; and he eminently promoted the dominion of man over the material world. He was the priest of nature's mysteries; and he taught men in what manner they might discover her profoundest secrets, and interpret those laws which nature has received from the great Author of all.

It is the object of this treatise to make our readers acquainted with Lord Bacon's philosophy, as it is contained in his great work, the *Novum Organon;* in which we find the principles of that improved method of conducting the inquiries of science, which has now so long and so happily prevailed. To accomplish this design with the more effect, it will be desirable, first, to draw their attention, in a few words, to the state in which Bacon found the world, as to knowledge and science, at the time when he flourished. For, as the returning light appears more glorious after the sun has been eclipsed,—and the order and beauty of nature would look doubly striking to an eye that had seen that chaos from which she first arose, when all was without form and void,—so, if we glance, but for a moment, at that darkness which so long overshadowed the human mind, and gave birth to so many phantoms and prodigies, under the name of science, this retrospect will serve to show more clearly the merits of a philosopher, who may be regarded as the morning star of that illustrious day which has since broken out upon mankind, and in the spirit of whose method, even the immortal NEWTON himself explored the heavens—by the aid of a sublime geometry, as with the

rod of an enchanter, dashed in pieces all the *cycles*, *epicycles*, and *crystal orbs* of a visionary antiquity; and established the true Copernican doctrine of astronomy on the solid basis of a most rigid and infallible demonstration.

In several of the fine arts, in which chiefly the taste and imagination are concerned, such as poetry, rhetoric, statuary, and architecture, the ancients, according to general opinion, have equalled, if not surpassed, any of the moderns. Homer and Demosthenes continue, notwithstanding the flux of time, to retain their station as the masters of eloquence and song; and those exquisite statues, the Venus and the Apollo, still command our admiration, as perfect models of what is chaste, and severe, and beautiful, in the art of sculpture. The ancients nobly distinguished themselves, also, in those more rigorous exercises of the understanding which are demanded by pure mathematics; in proof of which it is sufficient to quote the name of Euclid, and of Archimedes, whose discoveries in geometry and mixed science entitle him to be regarded as the *Newton* of all antiquity; but it was reserved for the moderns to invent a *calculus*—a new and more profound arithmetic, which was called for by a more exact acquaintance with nature herself, and was to be applied to that more improved state of natural science which is peculiar to later times: we allude to the doctrine of *fluxions*, or the *differential* method of Newton and Leibnitz, since cultivated, and applied to physical astronomy, with great success, by the French, and especially by La Place. In most of those branches of knowledge, however, which rest on the basis of *experiment* and *observation*, the ancients almost entirely failed. The case is, that to form *theories*, or systems of science and philosophy, from a hasty view of facts and appearances, is an easy task, since this can be done without the labor of close and patient thinking; and if antiquity be, in truth, as Bacon himself represents it, but the childhood and youth of the world, it is nothing more than we might expect, that, at that period of its existence, imagination should prevail over reason; and that the calmer and more successful exercises of the latter should not unfold themselves till a maturer age.

One instance, out of many in natural science, may suffice to convince the reader to what absurd and extravagant notions the mind can reconcile itself, when once permitted to rove into the regions of imagination, unrestrained by that strict and scientific method, so successfully pointed out by Lord Bacon, and which it is our present object to explain. *Cosmas Indopleustes*, who lived so late as the *sixth century*, affirmed that the earth was an oblong plane, surrounded by an impassable ocean; an immense mountain in the form of a cone, or sugar-loaf, placed in the north, was the centre around which the sun, moon and stars daily revolved: the shape of this mountain, and the slanting motion of the sun, accounted for the variable length of the days, and the changes of the seasons. The heavens were supposed to be an immense arch, one side of which rested on the earth, and the other on two mighty pillars beyond the sea; under this vault a multitude of angelic beings were employed in guiding the motions of the stars. Such was the theory which gravely presented itself for adoption, seven or eight centuries later in the world than Euclid, Archimedes, and Apollonius!

Abundant instances of almost equal absurdity might be collected from the opinions of the ancients, on various other branches of science. Take, for example, the doctrine of *sensation*, or feeling, in what was called the *Peripatetic* school, so called from a word signifying to *walk about*, because it was customary for the disciples to study and dispute as they walked in the *Lycæum*, a place at Athens which was appropriated to their use. Of this school the founder was Aristotle, a man of immense genius, who obtained the greatest popularity, and the most extensive influence over the opinions of mankind, of all the philosophers of antiquity, and who held the minds of men in a kind of intellectual bondage for about two thousand years. In the Peripatetic philosophy, what takes place in *sensation* was thus described: a sort of images, or, as they were termed, *sensible species*, that is, certain films of the shape of bodies, came off, it was said, from the objects of sense, and, arriving at the organs which were proper to them, were

admitted to the nerves, and by them conveyed to tne brain: here these images were impressed, as the engraving of a seal on wax, and being now refined into what were called *intellectual species*, the whole business of sensation and perception was supposed to be accounted for. Thus, by a jargon of words, were men taught to believe they understood the manner in which *matter* communicates with *mind* or *spirit*, and their operation upon each other, which all that has ever been said or written on the subject, shows to be inexplicable, and to be received simply as a *fact* in the constitution of sentient being.

Up to the time of Lord Bacon, Aristotle still maintained, in a very great degree, his dominion in the realms of philosophy—a dominion which, at some periods, had been scarcely less absolute over the minds of men, and far wider and more lasting, than ever his renowned pupil Alexander was able to secure over their bodies. Possessed of a most acute and penetrating mind, and a singular talent for minute investigations, he was qualified, in this respect, for philosophical inquiries, far more that ordinary men. His writings in natural history, in particular, constitute a mass of physical and anatomical facts, which must have resulted from a course of very diligent observations. Neglecting, however, that rigid and exact practical method which is essential to all natural science, too much devoted to subtile distinctions of words, and too ambitious of gaining an ascendency over the opinions of mankind, he pronounced too boldly on nature's operations, and spent his energies too often in useless or obscure questions. In his desire to set up his own dogmas, in opposition to ancient opinions, he is sometimes guilty of misrepresenting the philosophers of a remoter antiquity; and he frequently veils himself in an obscure and unintelligible jargon. Lord Bacon describes his propensity to tyrannize over men's minds, by saying that, "as though he had been of the race of the Ottomans, he thought he could not reign securely unless all his brethren were slain." Cicero, who seems to have had some respect for Aristotle's philosophy, acknowledges that, in his time, it was understood by very few even of the phi-

losophers themselves. His *Logic*, which is peculiarly his own, is undoubtedly a great effort of human ingenuity; it consists in an *analysis* of that process of the mind, which, however rapid, and almost imperceptible, must take place in all sound and correct reasoning. It furnishes the model to which all such reasoning may be reduced, and serves as a test by which the justice of an argument may be tried, if it be ever necessary thus minutely to put down all the steps by which the conclusion is arrived at. In the discoveries of science, it can, of course, afford little or no assistance; and it was the mistaken attempt to employ it for this purpose, that so long excluded the proper method of entering on philosophical researches, and filled the minds of men with mere words and confused notions. Bacon's observations on this subject, in his *Advancement of Learning*, show that his frequent condemnations of the logical philosophers were levelled against the extravagant perversions of Aristotle's *Dialectics*, with which these schoolmen were chargeable, and to which Aristotle himself had led the way. His logic was the engine by which, for ages, the minds of men were bewitched, in a manner that was altogether extraordinary, and diverted from things themselves to mere words.

The philosophy of Aristotle, which it would be foreign to the purpose of this treatise more than to characterize generally, without entering into its details, obtained the same credit at Rome, under the Cæsars, which it had already acquired in Greece; being patronized by both Julius and Augustus. Towards the close of the fifth century, the influence of Aristotle began to prevail over that of Plato in the Christian world. After considerably declining during the sixth century, it again revived; and in another century it had gained such an ascendency, that Aristotle seems to have been every where triumphant. Glosses, paraphrases, summaries, arguments, and dissertations on his works, were composed without end, as if to make "darkness visible." Many of the inhabitants of the West learned Arabic in order to read a translation of them in that language. The Latin tongue was made another medium of their circulation, and they were read in most

parts of the known world. Men were every where taught to believe in *matter*, *form*, and *privation*, as the origin of all things; that the heavens were self-existent, incorruptible, and unchangeable; and that all the stars were whirled round the earth in solid orbs! Aristotle's works were the great text-book of knowledge, and his logic was the only weapon of truth. Men's minds, instead of simply studying nature, were in an endless ferment about occult qualities and imaginary essences; little was talked of but *intention* and *remission*, *proportion* and *degree*, *infinity*, *formality*, *quiddity*, *individuality*, and innumerable other abstract notions. The Latin tongue, which was employed by these scholastics, was converted into a barbarous jargon, which a Roman would not have understood; and, in the end, the most sectarian bitterness was produced, sometimes ending in bloody contests. In the midst of these disputes, Aristotle was still the grand authority. Christians, Jews, and Mahometans, united in professing assent to the great lawgiver of human opinions: not Europe alone, but also Africa and Asia, acknowledged his dominion; and while his Greek originals were studied at Paris, translations were read in Persia and at Samarcand.

The rage for disputation, which now began to prevail in consequence of the spread of this philosophy, induced the council of Lateran, under Pope Innocent III., to proclaim a prohibition of the use of the physics and metaphysics of Aristotle; but, awful as were then the thunders of the Vatican, they were not mighty enough to dethrone him from that despotism over men's minds, which, by long custom, had now rendered itself almost omnipotent. The passion for the Aristotelian subtilties had become so general, that, notwithstanding Pope Innocent's decree, it was soon found necessary to favor publicly, in some degree at least, the study of their author; and, accordingly, his Dialectics, Physics, and Metaphysics, were received into the university of Paris by an express statute to that effect. In England, his doctrines were cherished with as great an eagerness as elsewhere. From about the end of the twelfth century, the very name of Aristotle operated like a charm;

his writings had obtained universal circulation, and, in some of the universities of Europe, statutes were framed which required the professors to promise, on oath, that, in their public lectures on philosophy, they would follow no other guide!

From this period till the close of the sixteenth century, though the authority of Aristotle still continued in the schools, the minds of men were gradually preparing to shake off his yoke, and a more propitious era was fast approaching. The revival of learning in the fifteenth century, the invention of the art of printing, and the reformation, had done much to prepare the world for that new light which was afterwards to be cast over the fields of science, hitherto covered with darkness, and peopled only with airy and delusive phantoms. A few distinguished men—as *John of Salisbury*, *Gros-tête*, bishop of Lincoln, *Roger Bacon*, *Ludovicus Vives*, and others—had taught mankind that neither the decrees of the Vatican, nor those of the Grecian schools, were incapable of being resisted. *Gilbert* had successfully investigated the laws of magnetic attraction, and furnished an excellent specimen of reasoning from experiment. In opposition to the system that was held by Aristotle and his followers, which made the earth the centre of the universe, *Copernicus* had revived the ancient Pythagorean doctrine of the earth's motion round the sun, and had discovered the true theory of the planets. *Galileo*, *Kepler*, *Gassendi*, and others who lived at the same time with Bacon, were acquiring a well-earned fame by their improvements in geometry and physics; and the whole world of science already sighed to be redeemed from the darkness of the middle ages, and the bondage of the schools. *Martin Luther*, who had been taught the philosophy of Aristotle in his youth, had expressed his contempt for its vanities, and rejected it with indignation. *Ramus*, also, had attacked the existing opinions at Paris, and disputed publicly against Aristotle's doctrines in the university of that city. Like many other honest followers of truth, however, in this wretched world, which has always loved darkness rather than light, he suffered severely for his boldness. As a

punishment for his presuming to question the infallibility of the great despot of all knowledge, in an edict of the French parliament, under Francis I., the said Peter Ramus is gravely pronounced to be "insolent, impudent, and a liar;" his books are, now, and for all time coming, condemned, suppressed, and abolished, and the author is solemnly prohibited from copying, or even reading, his own works. *Bruno*, *Campanella*, *Patricius*, *Nizolius*, and some others, also contributed their part to undermine the influence of Aristotle.

It was reserved, however, for Francis Bacon, Lord Verulam, to break the spell of the mighty enchanter of Stagira, and to give a final blow to the scholastic philosophy;—to make one grand and general attempt to deliver men's minds from the bondage of two thousand years;—to assert the right of that reason with which the beneficent Creator has endowed man, as above all authority merely human;—and to sketch the outline of one grand and comprehensive plan, that should include in it the endless varieties of our knowledge, and guide our inquiries in every branch. Born in the year 1561, and early entered as a student at Trinity College, Cambridge, this great genius soon began to feel dissatisfied with the vagueness and uncertainty of the existing state of knowledge, the want of connexion between the sciences and the arts, and the consequent uselessness of the reigning speculations as regarded the purposes of life. The more he thought on the subject, the more he was convinced of the vanity of the scholastic learning of the times, and of the necessity of a thorough reformation in the method of treating the knowledge of nature, by laying aside all conclusions not founded on observation and experiment. He saw plainly that a great part of the evil lay in the extensive influence which Aristotle still possessed in the schools; that *nature* and *fact* were neglected for the study of his doctrines, which were the arbiters in all disputes; the properties of matter, and the laws of motion, by which all effects are produced, were lost in useless distinctions and dry definitions; the powers of the mind were exhausted in grave trifling and solemn folly;

and the real advancement of human knowledge was altogether hopeless, so long as such a state of things prevailed. A century or two earlier, the contests about *names*, and *forms*, and *essences*, were sometimes more serious than a mere strife of tongues: they ended in actual bloodshed; while the disputants took the side either of *Occam*, "*the most subtil*," or *Duns Scotus*, "*the invincible*," the famous champions of the day; and if the din of this philosophical, or rather *un*philosophical war now raged no longer,—if those imposing titles were not now heard which had formerly been bestowed on the leaders of rival parties, such as the *most profound*, the *marvellous*, the *perspicuous*, the *irrefragable*, the *most resolute*, the *angelical*, the *seraphic doctor*,—it was that all inquiry had well nigh ceased, and the minds of men were cast, with a very few exceptions, into a profound slumber, and filled only with the romantic visions of an imaginary philosophy. Such had been the state of things at the time of Lord Bacon; and the brief notice we have taken of it may serve to throw light on the real value of his labors, which had for their object the establishment of a philosophy that is, in fact, no other than the philosophy of reason and common sense, in opposition to all mere theory and fancy, and to all imposition.

Under these circumstances Bacon wrote his Organon. His qualifications for this bold attempt to clear the barren wastes of science, and to sow the seeds of a new creation of useful knowledge, will be best seen by studying his doctrines. We shall, therefore, now proceed to give an account of this most important and considerable part of his general work, the *Instauratio Magna*, or *Instauration of the Sciences*. Its title was probably suggested by Aristotle's *Organon*, containing his Logic; it is called *Novum Organon Scientiarum*, or *A New Method of Studying the Sciences*, from the Greek word *organon*, which signifies an *instrument* or *machine*. The grand principle which characterizes this great work, and by the proper use of which its author proposes the advancement of all kinds of knowledge, is the principle of *Induction*, which means, literally, *a bringing in;* for the plan it unfolds is that of investigating

nature, and inquiring after truth, not by reasoning upon mere conjectures about nature's laws and properties, as philosophers had been too much accustomed to do before, but by *bringing together*, carefully and patiently, a variety of particular facts and instances; viewing these in all possible lights, and drawing, from a comparison of the whole, some general principle or truth that applies to all. The foundation of this philosophy lies, in short, in the *history of nature itself*—in making a laborious collection of the facts relating to any one subject of inquiry, previously to any attempt at forming a system or theory. Actual experiment, which Bacon significantly terms "asking questions of nature," must be resorted to, where experiments, as in chemistry, can be made: observations must be accurately collected, in the subjects proper to these, as astronomy; and conclusions are, in all cases, to be drawn only from what is actually witnessed, after the comparison of a sufficient number of facts, and a due regard to objections. In his treatment of this important subject of induction, a new and more rational employment of the faculties is exhibited than the world had ever seen; and never before was there laid down to the minds of men the true theory of investigating all truth, whether natural or moral: indeed, Bacon has well merited the appellations he has received—*the prophet of the arts*, and the *father of experimental philosophy*.

To point out the amazing success which has attended this system, which may be called the *Baconian* method, in the hands of the moderns, were an endless task: it would be to give nothing less than the history of science for the last two hundred years. The constellation of geniuses that rose in the next age mostly looked up to Bacon as their leading star. Newton himself was able to outshine them all, not merely by the energy of his own mind, but by his imbibing most deeply the spirit of this philosophy. No feature of Newton's intellect was more remarkable than the singular command he possessed over his imagination, by which he was enabled to construct theories, more surprising than all the visions of fancy, yet on a foundation that must remain unshaken so long as

the human mind and truth continue what they are. We may name his *Optics*, in passing, as a triumphant example of the *inductive* method, in which, by experiment and observation as the basis of his calculations, he has treated of the nature and properties of *light*, one of the most subtile of all things, in a manner that cannot fail to surprise and delight the reader—with so much accuracy and precision is this wonderful element reduced to certain laws, as truly as the most gross and solid bodies. Having found, by very accurate experiments, that light always proceeds in straight lines, and that the rays of it are reflected and refracted according to certain fixed and unchanging laws,—on this experience he establishes the whole theory of *optics*, or the science of *vision*; and thus this science is founded on the *induction* we speak of.

Again—the mere falling of a heavy body to the earth was found by Newton to involve principles which apply to all we know in mechanical philosophy; in other words, the descent of a tile from a house, or an apple from a tree, arises from the same cause which keeps the moon from leaving her proper course round the earth, and which retains all the planets in their paths round the sun: this principle or cause is called by the name of *gravity*. It was known from observation that gravity, or a tendency to approach the earth, belongs, generally, to all bodies near its surface; and it was ascertained that it is proportioned to the square of the distance; that is, if a body be attracted by the earth at a certain distance, with a certain force, and be afterwards removed to *twice* the distance, it will now be attracted *not half* as much, but only *one fourth* as much as it was before; and if it be removed to *three* times the first distance, it will be attracted not *one third* as much, but only *one ninth* as much as before, 4 being the square of 2, and 9 the square of 3. From these facts this mighty genius suspected that the same principle might extend to all nature; and thus, by the assistance of a profound geometry, he explained the motions of the heavenly bodies and demonstrated the system of the world.

That the rules laid down by Bacon had been carefully

studied by Newton, is evident from the use he makes of Bacon's phraseology. In his *Principia*, for instance, he gives the same latitude of meaning to the word *axiom* that Bacon does in his *Organon*. Bacon, by this term, means a general principle, obtained by experiment and observation, from which we may safely proceed to reason in all other instances; and Newton gives the name of *axioms* to the *laws of motion*, which, of course, are ascertained by the scrutiny of nature; he also terms *axioms* those general experimental truths, or *facts*, which form the groundwork of the science of optics. *Axiom*, however, in the language of Euclid, and of mathematicians generally, means a self-evident proposition. Mr. Dugald Stewart thinks that, in this and other instances, Newton followed Lord Bacon's phraseology "too implicitly." However this may be, it is certain Newton was familiar with Bacon's works.

In the *chemistry* of modern times, also, we have the most astonishing examples of the success of the inductive, or experimental method. Until this was employed, no part of science was more fanciful; so that it has justly been remarked, that chemistry, in the middle ages, might be said to have an *elective attraction* for all that was absurd and extravagant in other parts of knowledge. It is true that, before the darkness of these ages had passed away, *Paracelsus* conferred great benefits on the world by the application of chemistry to medicine; and *Van Helmont*, notwithstanding the extravagancies with which his imagination was filled, by the discovery of elastic fluids, did his part to form the new chemistry; but it was the work of those who have had the opportunity of thoroughly imbibing the spirit of the Baconian philosophy, as applied by Newton, effectually to deliver chemistry from quackery and romance, and to frame such a system as that which now exists.

Lord Bacon, in support of the importance of the *inductive* method, lays down the following fundamental principle, as his first and leading *aphorism* concerning the "Interpretation of nature, and man's dominion over it"—

a principle which, obvious as it seems, had never been properly acted on by philosophers:—"Man, the servant and interpreter of nature, can only understand and act in proportion as he observes or contemplates the order of nature; more he can neither know nor do." This general principle of Bacon is undoubtedly the foundation of all our real knowledge. The science of the philosopher differs in degree only, *not* in kind, from that information which is the fruit of the commonest experience. Everybody knows that cold produces ice and snow; that the sun is higher in the sky in summer than in winter; that in pits and mines the air sometimes burns, and explodes like gunpowder. Now, the moment we depart from these mere facts, and begin to consider their causes, and in what circumstances they are likely to happen again, we begin to apply *experience* to science—we reason by *induction*. It cannot be doubted that this inductive method is, to a certain extent, natural to the mind. The foundation of it lies in our expecting the *same effects from the same causes;* for this is the groundwork of reasoning from particular facts to general, or what is called "*generalization*." This expectation seems to be an original principle implanted in the human mind by the beneficent Creator; and without which we could know nothing, and never be safe from danger. It goes before experience, and is the guide of it. A child who for the first time approaches too near the flame of any substance that is in a state of combustion, or burning, so as to hurt himself, afterwards proverbially dreads the fire; connecting in his mind the remembrance of the pain he has felt, with the touching of any part of his body with the flame. It is evident he expects the same effect to follow from the same or a similar cause; and the resemblance between the flame of a candle and that of the fire would, it is likely, put him on his guard against a similar disaster from that source also. Now, this is a species of *induction*, though not founded on an enlarged experience; and it is probable the child will now come to have the same fear of everything bearing the appearance of flame. He might expect that the same effect must arise

from contact with the flame of *alcohol*, or spirit of wine, for instance, until informed that it was possible to touch this without being burnt. Hence the necessity of a sufficient experience, before we form any general principle.

A remarkable instance of this necessity, and one drawn from the more exact part of science, is mentioned by Euler, in his Memoirs of Berlin. It happens that in the formula $x^2 + x + 41$, if x be made successively equal to 0, 1, 2, 3, 4, 5, etc., the results will be a series of which the first forty terms are all *prime* numbers—that is, numbers which have no divisors, or which cannot be divided into any number of equal integral parts less than the number of units of which they are composed: hence it may be supposed the law was general;—or, in other words, for the sake of any of our readers who have not made themselves acquainted with algebra, that any number whatever, multiplied by itself, and then added to itself, together with the number 41, would make a prime number. It happens, however, that in the very next, or forty-first term, the result is a *composite* number—that is, a number that can be divided by some smaller number, without a remainder; and thus the rule is false. Now, it is the great design of the *Novum Organum* to point out the method of a strict and enlarged experimental or inductive reasoning, especially, though by no means exclusively, in reference to the study of *physics*, or natural philosophy. This work may be regarded as a more useful and more extensive system of reasoning than any that went before it; not consisting of *syllogisms* and the modes of argument that were then in use, which, however correct, provided the premises be true, could, after all, only serve for the arrangement of truths already known, or for detecting very obvious and gross fallacies in argument, and for classifying such truths and fallacies, but an art leading to invention, and productive of discoveries of the highest importance to the general uses of human life. These discoveries are proposed to be accomplished by turning our attention from mere words to things themselves; from all those frivolous and childish speculations which only dazzle

without illuminating the understanding, to a sober and rational method of investigating the operations and laws of nature,—a method well calculated to recommend itself to those whose only object is *truth*.

Lord Bacon sets out by condemning the two opposite errors, which, up to his time, had proved equally injurious to a just acquaintance with nature; the one that of magisterially pronouncing on her operations, as if *all* were explored and known, and nothing further were to be discovered; by which supposition all inquiry would, of course, be prevented as useless; the other error that of the sceptic philosophers, who, proceeding to the opposite extreme, declared that *nothing* can be known, and endeavored, by distrusting the clearest notices of sense and consciousness, to convince themselves of this absurd and inconsistent notion. Those of the ancient Greeks were more worthy of our imitation, whose writings are now lost, but who seem to have held a middle course, and, though they complained of the mystery in which nature often wrapped herself, still kept on their pursuit, and did not allow themselves long to lose sight of their object. Even these philosophers, however, do not appear to have applied a sufficient *rule* and *method* in their inquiries, but placed too much reliance on subtilty of mind and random conjecture. The art of logic, so much extolled by the ancients, certainly came too late to minds already prepossessed by error: hence, by the perversion of this instrument, the aberrations of the human understanding were only fixed and rendered permanent, instead of being corrected and removed; the chains of prejudice were riveted, and loaded with gaudy ornaments. It is evident that the mind needs direction and regulation, by some right method of employing its faculties, as much as the body needs the assistance of the mechanical powers in raising large and heavy weights. In such a method the ancients were altogether deficient. Yet, by way of conciliation, Bacon observes that he is still perfectly willing to leave the ancients in possession of all the honor that is due to them. The method of science, however, here

proposed, being so little known to them, no room, he conceives, is left for rivalship and envy. He contends not for victory, but for utility and truth. If any persons, from want of time, or other causes, are unable to pursue this more laborious method, he says they may still attempt what they can, by framing systems and theories, which he terms the mode of *anticipation of the mind;* others, who are more worthy sons of science, must follow *his* plan of induction, or *the interpretation of nature,* as it is here laid down—a method on which it is the more necessary to insist, because many examples have occurred, since Bacon's time, of the bad consequences of neglecting it. Of this, no less names than *Descartes* and *Leibnitz* were early examples; men endowed with every faculty of the mind that most fits for philosophical investigations —with the happiest genius for science.

The body of the Novum Organum is divided into two general parts. The former of these, which is intended to introduce the latter, is calculated to prepare the mind for receiving and employing the doctrine contained in the second part, which delivers the new method of proceeding in all kinds of inquiries, in order to the acquisition of a more accurate knowledge of the works of nature, and a more extensive dominion over it. As the whole book is quaintly divided into *aphorisms,* or short portions, founded on sententious remarks, and accompanied with illustrations, we shall not attempt to conduct our readers though each of these portions separately, which would be almost to present the whole; but, hoping that those who have the opportunity of doing so, will feel induced to read the original work, or a translation of it, for themselves, we shall simply endeavor to condense its principles, and shall throw it into sections adapted to our present purpose.

I. *General Prefatory Remarks.*

The first thirty-seven aphorisms, which we may call our *first section* of the former part of the work, are chiefly occupied in attempting to remove ancient prejudices, and

to procure a fair and candid attention to a book which, at the time of its publication, must have had so much to contend against. It is deplored by Bacon, that, for want of a right method of study, little effects had resulted, up to the close of the sixteenth century, from the labors of men engaged in the pursuit of science; for knowledge is the same thing as power; and where there is little sound knowledge of nature, there will be little power gained over her. This must always have been the state of things, unless means before untried had been employed in the improvement of the sciences. That improvement could not be left to mere accident as heretofore, when each following age only re-echoed the voice of the preceding, and contented itself with pompously extolling the existing delusive methods of philosophy, to the neglect of one more genuine and scientific. The philosophy of nature Bacon compares to "a vast pyramid, which ought to have the history of nature for its basis:" those who strive to erect it by the force of abstract speculation, he likens to the giants of old, who, according to the poets, endeavored to throw mount Ossa upon Pelion, and Olympus upon Ossa. The only hope on which to found all real advancement in knowledge, must arise from a strict experimental method, that is, the examination of a sufficient number of particular instances on both sides the question at issue, so that, when all the exceptions are properly made, some useful and important truth may remain as a principle to proceed on, in further inquiry. When examined on this inductive principle, most of the common notions existing when the *Novum Organum* was written, were quite unsatisfactory; those, for instance, relating to *gravity*, *attraction*, the *elements*, *matter*, *form*—all these, and many more, as taught in the sixteenth century, were but ill-defined and fantastical notions. Even many of our common-sense ideas, as those relating to our sensations and reasonings, though they can scarcely in themselves greatly deceive us, yet may these be much obscured and perplexed by a false mode of philosophizing. For instance, the supposed necessity of the objects of sense

being actually present with the mind that perceives them, gave rise to the *notion* of *images*—an image of a horse must be *in* the mind, or the horse could not be seen; whereas it is evident, that *seeing* is a fact in the nature of man: how the impression is conveyed from the nerves and brain to the mind, we know not.

The mode of searching after truth that had always been in vogue was, at the best, from observing, not very rigidly, a few particulars, to rise at once to some *general* axiom or conclusion; but the only genuine method, Bacon observes, is, to advance gradually from the notices the senses give us in particular instances, and those sufficiently numerous, to some *lesser* axiom or principle, and then gradually to proceed to some still more general principle, till at length you form some grand and final conclusion. The understanding seems but too naturally to adopt the former of these two methods, which is calculated most effectually to prevent all advances in knowledge and science. It is the object of science to see things as they are in nature, and not in appearance merely: but "there is a wide difference," says Lord Bacon, "between the *idols* of the human mind, and the *ideas* of the divine mind; that is, between certain vain notions, and the real characters and impressions that are stamped upon the creatures, as they are actually found." We may illustrate this by a reference to the Ptolemaic System of Astronomy, which was founded on the false and hasty notion of the *apparent* motions of the heavenly bodies being the *real* ones. The sun, moon, and stars, seem to move round the earth once in twenty-four hours: hence the rude and Gothic notion that the earth was the centre around which they are all actually whirled; whereas, by a successful cultivation of a proper method, the truth is now demonstrated to be that the sun, and not the earth, is the centre of the mundane system, and is, with respect to the earth at least, nearly at rest. "The method of *anticipating nature*," says Bacon, "rash, hasty and unphilosophical as it is, has nevertheless a much greater power than the other, to entrap the assent of the mind, which is too apt to be delighted with its

own conjectures, and to allow the imagination to be struck and filled with its own plausible subtilties: whereas *interpretations of nature*, or real truths arrived at by induction, being separately and more slowly collected, cannot so suddenly arrest the mind; and when the conclusion actually arrives, it may so oppose prejudice, and appear so paradoxical, as to be in danger of not being received, notwithstanding the evidence that supports it, "like mysteries of faith."

The method of *anticipation*, however, or of dictating to nature what she and her operations are to be, could never, of course, avail to promote real science, whatever talents might be engaged in it. *Tycho Brahe* thus *anticipated* nature, in taking it as a certain truth that the earth must be at rest. For though he was too well acquainted with the planetary motions to suppose their centre any other than the sun, yet, in order to preserve his favorite notion that the earth did not move, he supposed the sun, with all the planets, to be carried annually round it; while these latter revolved in their proper orbits round the sun: and, having rejected the Copernican doctrine of the daily motion of the earth round its own axis, he was obliged to retain the most violent part of the system of Ptolemy, and to suppose that the whole universe was carried round the earth every day. It was thus, also, that the great *Kepler*, the contemporary of Bacon, imagined that the planets *must* be *six* in number, and must have orbits of certain dimensions, because of certain properties of numbers, and of plane and solid figures, with which he fancied they corresponded. These speculations he published in 1596 in his "*Mystery of the World*;" and on sending a copy of his book to Tycho Brahe, he received from him the advice, "first to lay a solid foundation in *observations*, and then, by ascending from them, to strive to come at the causes of things." To this excellent advice, as Maclaurin observes, we owe Kepler's more solid discoveries; for, availing himself of Tycho Brahe's astronomical observations, he, from them, discovered the laws of the planetary motions, known ever since by his own name.

Huygens, a celebrated Dutch geometrician and astronomer, and who lived later, suffered himself to be imposed on in a similar way; for, having discovered one of Saturn's moons, this, added to the four moons of Jupiter, and the one belonging to our globe, made up the number six; the number of the primary planets then known being also six; and the number six being a *perfect* number—that is, a number that is equal to the sum of the equal parts into which it can be divided—Huygens affirmed that the number of the planets was complete, and that it was in vain to look for any more: we need not remark that this mystical speculation has since been disproved by fact. Now it was the praise of Lord Bacon to endeavor to remove from men's minds this superstitious tendency to rest in preconceived notions, which so much prevailed, and which was encouraged by some who were greatly his superiors in the abstract sciences. "Though the labors and capacities of all men," says he, "in all ages, could be united and continued, they could effect no considerable progress in science by *anticipation* of nature; since radical errors in the mind's first digestion are not to be cured by the excellence of its functions, or by any succeeding remedies. Unless men choose to move always in a circle without advancing, we have but one simple method left; namely, that of leading them to particulars, to their order and connection. They must be contented, for a time at least, to forsake their own notions, and to become acquainted with things themselves. Our method has some resemblance to that of the Sceptics at the outset, but differs widely from it, and is directly opposed to it in the end. They foolishly assert that nothing can be known; we say that little is to be expected from the existing method; they contradict reason and common sense; we endeavor to assist both."

II. *The Idols of the Mind; or Grand Sources of Prejudice.*

Lord Bacon philosophically points out, with great exactness, various general sources of those *errors* which

men are apt to commit in forming their notions of things; and he shows how very great an obstacle they form to the progress of our knowledge, and the acquisition of truth. "The *Idols*, or false notions of the mind," he says, "so deeply fix themselves in it, that they not only shut up the avenues through which truth might enter, but, even when it has entered, they will again be presenting themselves, and will be troublesome in the advancement of the sciences, unless men, being aware of them beforehand, guard against them with all possible diligence." As no part of Bacon's works is more valuable than this, or more important to all who are in pursuit of knowledge and truth, we shall give some detail of it to our readers. He strikingly, though in his usual quaint style, calls the prejudices that check the progress of truth, by the name of *Idols*, because mankind are apt to pay homage to these, instead of regarding truth; as they have offered to imaginary deities the worship which is due only to the true God.

These prejudices and prepossessions are divided into four classes, which are called *Idols* of the *Tribe; Idols* of the *Den; Idols* of the *Market;* and *Idols* of the *Theatre*. These sources of error are peculiarly deserving of notice, because they will be found, if we mistake not, to include the principal causes, which, in all cases, have a tendency to obstruct the pursuit of truth, whether natural or moral. They constitute a sort of infection from which the mind must be purified, before it can enter with soundness and vigor, and with the best effect, into any sort of inquiry which has truth, and truth only, for its object. "While the rules Lord Bacon gives us," says the late Dr. Thomas Brown, "are rules of physical investigation, the temple which he purified was not that of nature itself, but the temple of the mind; in its inmost sanctuaries were all the idols which he overthrew; and it was not till these were removed, that Truth would deign to unveil herself to adoration."

1. The *Idola Tribus*, or the *Idols* of the Tribe, the *first* class of prejudices, are so called because they are common to the whole *tribe*, or *race* of mankind; they are,

in fact, *those general prejudices which arise from the infirmity of human nature itself.* "The understanding of man," says our author, "is like a mirror whose surface is not true, and so, mixing its own imperfection with the nature of things, distorts and perverts them." For instance, there is a tendency in the mind to suppose a greater *uniformity* in Nature than she actually possesses. We are always disposed to imagine parallels, correspondencies, and relations that may not actually exist. Hence the supposition that the heavenly bodies must all move in perfect circles, because the orbits of the planets were perceived to return into themselves: this was universally believed by the old astronomers, till Kepler disproved it a few years before Bacon wrote, by showing that the planets move in elliptical or oval orbits. Hence the ancient notion that the element of fire, with its *orb*, must be added to air, earth, and water, to make up the *even number* of what they called the *four elements.* Bacon's prediction that the sources of error would return, and be likely to mingle with science even in its most flourishing condition, has been verified with respect to this particular illusion, in the case of sciences which in his time were scarcely in existence. When it was found that a considerable part of the earth's surface consisted of minerals, disposed in horizontal strata, or layers, it was immediately concluded that the whole exterior surface either is or has been composed of such layers; and on this assumed principle entire theories of the earth have been constructed.

Again, the mind has a wonderful facility also of being imposed on by *prepossessions.* If once pleased with any notion, it immediately endeavors to make every thing agree with this, even in the face of evidence to the contrary. It gets over opposing instances and examples, either by altogether neglecting them, or by inventing some subtile distinction which shall still maintain the favorite principle with which it first set out. Dreams, omens, and astrological predictions, are cases of this kind, in which the instances of failure are passed over by the superstitious with little notice, while those instances in which the event

20

corresponds to the supposed preternatural intimation of it are carefully remembered. This prepossession of the mind cannot endure exceptions to rules, and negative instances; though these are, in fact, of the greatest importance in establishing axioms or general principles.

The *imagination*, also, is apt to be overpowered with whatever at once strikes and seems to fill it; and the mind, imperceptibly yielding to this impression, readily comes to some conclusion, not waiting for the gradual processes of the understanding, to try general principles by the test of various, remote, and dissimilar instances; which can never be done without following rigid rules, and submitting the faculties to violent restraints.

The *restless activity* of the human powers, moreover, aids the force of general prejudices. The mind is ambitious of understanding what is incomprehensible. It attempts to grasp what is beyond its power, instead of being content with some proper resting-place for the natural weakness and limitation of its faculties. It wearies itself in its endeavor to comprehend such ideas as *space, time, eternity, infinity;* and it is still more apt to be misled, Bacon thinks, by its desire to discover the *final causes* of things, that is, the *uses*, or *ends*, which the Creator had in view in forming them. The phrase *final cause* was first introduced by Aristotle, and the inclusion of this among *causes* in general as objects of inquiry, had the effect of diverting such minds as those of his followers from the study of nature to mere speculations. We must therefore remember that the hint which Bacon here throws out on this subject, and what he says more on it in his other works, always has a reference to *final causes* as treated by the schoolmen. He objects to these being included, as a branch of *natural* science; but it cannot be supposed that his remarks on this subject arose from the same source which produced the prejudice against final causes that so generally prevailed in France in the eighteenth century. Bacon had no bias towards atheism: he censures Aristotle for "substituting Nature instead of God, as the fountain of *final causes;* and for treating them rather

as subservient to logic than theology;" and in his Essays he finely remarks, "I had rather believe all the fables in the Legend, and the Talmud, and the Alcoran, than that this universal frame is without a mind. While the mind of man looketh at second causes scattered, it may sometimes rest in them, and go no farther; but when it beholdeth the chain of them confederate and linked together, it must needs fly to Providence and Deity."

Notwithstanding Lord Bacon's objection to final causes as a subject of philosophical inquiry, it must be allowed that, apart from the charm which the final causes, or ends of things, lend to Nature, when they are satisfactorily perceived, which is the moral use of them, there are some cases in which a consideration of them has conduced to actual discoveries in science. It was noticing the situation of the valves in the veins of the animal body, for instance, that led to the great discovery of the circulation of the blood. Harvey, who was its author, perceived that these valves, in some parts of the body, were so placed as to give a free passage to the blood towards the heart, and to exclude its return the same way. He thought there must be some particular *design* in this; and no design appeared more probable than that, since the blood could not well, because of the interposing valves, be sent by the veins to the limbs, it should be sent through the arteries, and return through the veins, whose valves did not oppose its course that way. This fact, however, and others which might be mentioned in illustration of this subject, were not known to Bacon; and the great abuse of the speculation on final causes by the schoolmen not unnaturally led him to an unreasonable distrust of it.

The *influence of the will and affections on the understanding*, or what may be termed the *moral* state of the mind, may also greatly affect our opinions. "The light of the understanding," says our author, "is not a dry or pure light, but it receives a tincture from the will and the affections, and forms the sciences accordingly; for men are most willing to believe what they most desire." Hence, he observes, "difficulties are rejected through

impatience; the deeper things of Nature are dreaded through a certain awe; experience is discarded through pride; truth when it limits our hopes; paradox is shunned through fear of vulgar opposition; and thus in innumerable ways, and often imperceptibly, do the affections and passions tinge the understanding with their own coloring."

The *fallacy and incompetency of the senses* are an additional source of mistake and error. Inquiry commonly ends in what is seen on the near surface of things, while the organization, the texture, or the inward changes of bodies, are unknown. On these, however, chemistry depends." Lord Bacon considers this incompetency and dullness of the senses as one of the greatest impediments to an exact knowledge of nature. "Nor can instruments," he adds, "here be of any great service, since all true interpretations of nature must be made by suitable and proper trials, in which the senses judge of experiment only, and experiment is the judge of nature and fact." He complains, by way of example, that in his time even the properties of the common air of the atmosphere, and of all the agents, still more subtile than the air itself, of which he supposed there might be many, were almost entirely unknown. What would he have said, could he have witnessed the application of the inductive philosophy to the discovery of the properties of the various kinds of *gases*—the researches of Newton respecting *light*—the experiments of Franklin in *electricity*—the powerful agency of *galvanism*, which has produced new creations in chemistry, and changed the whole face of that interesting and useful science!

Lastly, there is a tendency in the mind to *abstraction or generalization*, which should be carefully watched as a likely source of error. It is less troublesome to reason upon fancied general notions, than to make experiments. "But Nature," says our author, "must be anatomized rather than abstracted: matter should be considered in all its states and transformations; so ought motion and its laws; but for the Aristotelian abstract *forms*, they are *idols* or *figments* of the mind."—These seven particular

causes, then, may be borne in mind as among the chief general prejudices, which are apt, often insensibly, to militate against the discovery of truth, and the advancement of science: too great a tendency to suppose a *perfect uniformity* in nature; *hasty prepossessions* in respect to some *favorite idea;* the influence of the *imagination;* the *restless activity* of the human mind; the bias the *will and affections* give to the judgment; the *imperfection* of the *organs* of *sense;* and the love of *abstractions and generalizations.*

2. The *second* class of prejudices introduced by this sagacious observer of human nature, as tending to obstruct the progress of truth and knowledge of all kinds, he terms *Idola Specus*—Idols of the *Cave* or *Den;* that is, *those prejudices which stamp upon each mind its own peculiar character, and are identified with every individual man.* "Idols of the den," says the *Novum Organum,* "are the idols of each particular person; for in addition to the general waywardness of human nature, every man has his own peculiar *den* or *cavern,* which breaks and corrupts the light of nature,—either on account of his constitution and disposition of mind—his education and the society he keeps—his course of reading and the authorities he most respects—his peculiar impressions as they may be made on a mind that is pre-occupied and pre-possessed, or is in a calm and unbiased frame: so that the human spirit, as it is differently disposed in different individuals, is a thing fluctuating, disorderly, and almost accidental. Hence Heraclitus well observes that men seek the sciences in their lesser worlds, and not in the great and common world of nature." In another place, these idols of the den are spoken of, in the figurative language of Bacon, as "each man's particular demon, or seducing familiar spirit;" and again, every mind is compared to "a glass, with its surface differently cut, so as differently to receive, reflect, and refract the rays of light that fall upon it."

Some of these private prejudices he justly regards as requiring peculiar caution, because they possess the greatest tendency to pervert the mind. The *particular studies,* for

20 *

instance, to which a person has been addicted—more especially, if he has any claim to be an inventor, may warp his judgment in other pursuits, and tend to corrupt his notions. It was in this way that Aristotle, through his fondness for distinctions and quiddities, made his natural philosophy a mere slave to his logic, and so rendered it little else than a useless source of disputation. *Gilbert*, of Colchester, is another example. In his "*Treatise on the Magnet*," he gives a specimen of experimental inquiry carried on with considerable correctness and success; but he tried to make his magnetism a general principle, considering it to pervade all Nature. It is but fair to acknowledge his merit, however, for "to him," as Dr. Priestley observes, "we owe a great augmentation of the list of electrical bodies, and of the bodies on which electrics can act: though his theory on this subject is imperfect, he may justly be called the father of modern electricity." Of late years, this species of fondness for theory has been discovered in attempts to account for the motion of the planets by electricity; and electricity and galvanism together have been employed to explain gravitation, the affinities of chemistry, and even the laws of vegetable and animal life. At an earlier period, Des Cartes, after Bacon had so well written against theories, endeavored, in medicine, to combine Van Helmont's doctrine of *fermentation* with his own beloved notions respecting *vortices;* which he thus brought down from heaven (where, as he supposed, they guided the planets in their orbits) to earth, in order to explain the chief functions of the animal body. Hence he formed a chemico-mechanical system of medicine which was eagerly received by the Dutch physicians of his time. Thus may one favorite pursuit be suffered to give a tincture to every other branch of knowledge, and to corrupt it. "The tribe of chemists," says Bacon, "have constructed a fantastical philosophy from a few experiments of the furnace." None certainly of the professed inquirers after truth, up to his time, were ever more extravagant and fanciful than the experimenters in chemistry; witness the Archæus of Van Hel-

mont, and his army of spiritual agents, derived from the elastic fluids.

Among the private prejudices or the sources of error arising from the mental constitution of individuals, the natural *difference of men's capacities* is enumerated. Some minds, Lord Bacon thinks, are fitted more for discrimination, while others content themselves with merely noticing resemblances. "The great and radical difference of men's capacities," he says, "as to philosophy and the sciences, lies in this, that some are stronger and more fitted to observe the differences of things, and others to observe their correspondences: for a steady and sharp genius can fix its contemplations, and dwell and fasten upon all the subtilty of differences; whilst a sublime and ready genius perceives and compares the smallest and most general agreements of things. Both minds easily fall into excess, by grasping either at the dividing scale or the shadows of things."

With greater clearness and perspicuity, he adds to these personal prejudices and tendencies, the *attachment to times*, in forming our ideas of truth and excellence. Some men have cherished an idolatrous admiration of the ancients, and have scarcely allowed even a comparison to be made between their works, and the monuments of modern genius. Thus the poetry of Milton has been underrated by those who have been so devoted to the remains of classical antiquity, as to be almost incapable of awarding due merit to productions in the vulgar tongue: witness the contests respecting the superiority of ancient or modern learning. On the other hand, while every thing modern has been despised only because it is not ancient, some have been misled by the opposite cast of mind, and have been inflamed with a constant passion for novelty; being disposed to yield little or no respect to antiquity, even where the experience of past ages might be of great service to us. This kind of prejudice has greatly declined, however, since Bacon's time—*truth*, and not the establishment of sects, having happily become the leading object of philosophical inquiries; "for truth," says he, "is not to be derived from

any felicity of times, which is an uncertain thing, but from the light of nature and experience, which is eternal."

He exemplifies another kind of *particular* prejudices, or of the *Idola Specus*, by comparing the school of Leucippus and Democritus, among the ancients, to the "other philosophies," alluding probably to those of Pythagoras, and of Socrates, Plato, and the Academics. Leucippus, Democritus and Epicurus were *atomists*,—they taught that the whole universe is composed of either *atoms* or a *vacuum*, and that it was by the accidental meeting together of these atoms that the world assumed its present form and appearance. "This school," says Bacon, "is so taken up with the particles of things, as almost to neglect their structure; whilst the other views the fabrication of things with such astonishment, as not to attend to the simplicity of nature;" referring to the lofty speculations and flights of imagination that characterized the Platonic school. "To contemplate nature and bodies in their simple elements," he quaintly remarks, "breaks and grinds the understanding; and to consider them in their configurations and compositions blunts and relaxes it." This *exclusive predilection for the minute or the vast* in nature, by which some of the ancient schools were marked, much resembles the second order of prejudices which is mentioned under this class. "In this manner, then," concludes the account of these prejudices, "let contemplative wisdom proceed in dislodging and chasing away the *idols* of the *den*, which principally have their rise from *prevalent studies; excess of composition and division; affections for times;* and from the *great or small size of objects.*"

3. Another class of prejudices to be carefully avoided in our inquiries after *truth*, are termed, in the figurative but expressive language of Lord Bacon, *Idola Fori; Idols of the Market-place;* that is, *prejudices arising from mere words and terms in our common intercourse with mankind:* they proceed, in short, from the *imperfection of language*. These prejudices he pronounces "the most troublesome of all." "Words," says he, "are for the most part accom-

modated to the notions of the vulgar, and they define things by bounds that are most obvious to common minds; and when a more acute understanding, or a more accurate observation, would remove these boundaries, and place them more according to nature, words *cry out and forbid.*" A familiar instance of this may be taken from our common mode of speech with regard to the heavenly bodies. We say of the *sun*, that it *rises* and *sets*, though every one, but the most ignorant, is aware that this is not strictly true, since the sun is stationary with regard to the planetary system; its *apparent* motion being owing to the *real* motion of the earth. In this instance, however, the delusion which words might produce, is obviated by the popular knowledge of astronomy which prevails. In many cases it is certain that the want of accuracy in the use of words and phrases has proved a great barrier to the pursuit and attainment of truth. How many violent disputes have there been, for instance, on *liberty* and *necessity* among ethical writers, while neither party has taken the pains first to say what he meant by these words; which might have saved both much time and much angry contention. Hence, in order to avoid controversies respecting mere words and terms, it is recommended to begin with these according to the "wise method of the mathematicians," and to reduce them to order and certainty by *definitions.* "Yet," it is justly observed, "these definitions themselves cannot wholly remedy the evil; for definitions consist of words, and words produce words; so that recourse must be had to particular instances."

Lord Bacon's meaning may be illustrated by such words as *sensation*, *will*, *benevolence.* We may define sensation, and say it is *feeling;* but what is *feeling?* What, for instance, is the feeling or sensation of *cold?* What is the sensation of *seeing?* None can describe these, it is obvious, to a person supposed never to have experienced them. *Will* may be defined *volition;* but this again is a mere translation; and if an intelligent being could be imagined who had never actually *willed any thing*, nor ever had any *desire* in his mind to do or say any thing, it would

be utterly impossible to make him understand what *willing* is. A being of simple malevolence, or one who had never felt towards other beings any thing but *hatred*, could have no idea of the emotion of *benevolence* towards others: he could not know what it is to love them. But when a child once understands that *sensation* is a general name for all those immediate effects which arise from objects acting upon any of the organs of sense—a name for *seeing*, *hearing*, *smelling*, *tasting*, and *feeling*, indifferently; when he learns that *willing* is that state of the mind which directly goes before any deliberate action; or that *benevolence* or *love* is a term expressing certain natural and delightful emotions towards his parents, brothers, sisters, and friends,—he then understands the meaning of these words by instances and examples. Or, if I wished to convey to the mind of another person the meaning of the word *gravitation*, or *attraction*, as it is employed in the Newtonian philosophy, instead of merely saying it is the *tendency* bodies have *towards each other*, I might state the simple fact, and say, when a body is let fall from any height, it proceeds invariably to the earth, and more swiftly in proportion as it arrives nearer the surface: this is what is meant by saying that the body is *attracted* or *gravitates* with accelerated velocity toward the earth: and when the inquirer is further informed that the earth itself also proceeds, however little, toward the falling body, and that the sun, moon, earth, and planets, all mutually move toward each other, more or less, in the same manner, the general idea of what is intended by attraction or gravitation is gained; and it is understood simply to be a name for a certain *fact*, or *law* in the operations of nature, or rather of nature's Divine and Almighty Architect.

Mankind are apt to be led into errors by words in *two* principal *ways;* and first by the names of *things* which have *no existence* whatever. Of this kind, says Lord Bacon, are such as "fortune, the primum mobile, orbs of the planets, the element of fire, and the like figments which arise from false and imaginary theories." It is almost unnecessary to remind our readers that all such words as *chance*, *fortune*, *luck*, etc., are only names for human ignorance

of a cause; and that in all the cases in which these words are applied to any kind of circumstances that occur either in the natural or moral world, there is the same necessity for supposing an agency of the Deity as in the greatest, and, to us, most certain events. *Primum mobile*, or the first mover, in Ptolemy's astronomy, was a supposed immense sphere, or hollow globe, which included within it all the spheres, or *orbs of the planets*, and fixed stars, and turned itself and all these round the earth in twenty-four hours! Idols of this kind, however, it is observed, are the more easily dislodged from the mind, because the direct remedy for them is the constant rejection of all mere theory.

But there is another species of delusion which may arise from words, that is likely to produce greater perplexity, and is avoided with greater difficulty. This delusion is produced *when words do not agree* to the *things* they are intended to signify, but are confused and ill-defined. Bacon adduces the various meanings that were formerly given to the word *humidum*, or *moisture*, as an example of this uncertainty: he shows that, according to the vague manner in which the word was used, it would apply to the most dissimilar things, and that *flame*, and *small dust* or *powder*, and *glass*, might all, on this principle, be said to possess *moisture*. It is evident that this uncertainty in the application of the term *humidity* or the quality of *moisture* arose from not considering moisture as a *relative* idea. For instance, quicksilver, with relation to some substances, as our hands or our clothes, is *not humid;* but it may be regarded so with reference to tin, lead, or gold; for it will adhere to their surfaces, and render them soft and moist. Even water does not wet all things, for it runs off in round drops from the leaves of many plants, the feathers of birds, etc.; so that water itself is no more moist with regard to these, than quicksilver is with regard to our hands; unless by moisture we mean soaking with water merely. Our great philosopher complains that, in general, the notions of *quality* in bodies, were in his time exceedingly confused. Such were the notions of *gravity*, *density*, *tenuity*, *levity*.

From what we know, indeed, of the philosophism which then prevailed, all attempts to reason on these terms must have been like grasping a shadow or beating the air. The words used to express the *changes* which bodies undergo, were also extremely vague and undefined, as *generation, corruption, alteration.* So likewise general names of substances, as *earth;* and *air,* or vapor. It was reserved for the science of modern times to use a more precise language, and to aspire at a magnanimity almost unknown to the ancients—that of frankly acknowledging man's ignorance, and the limitation of his faculties, rather than taking refuge in the darkness of an ambiguous phraseology. Our readers will perceive from all that has been said, how much accuracy and precision of language depend on the advancement of science; indeed they mutually promote each other. What has been effected in chemistry by a reformation in the use of terms is well known. An imitation of this precision, so far as the nature of the given subject will allow, must lie at the root of advancement, not only in natural, but equally in moral and intellectual science; and here, as in chemistry itself, the advice of Bergman to Morveau will advantageously apply: "In reforming the nomenclature, spare no word that is improper."

4. The last general sources of prejudice adduced, as obstructing philosophical discoveries, are what are termed *Idola Theatri;* Idols of the Theatre; or the *prejudices and perversions of the mind arising from the fabulous and visionary theories and the romantic philosophies* that so long prevailed in the world. "We call them Idols of the Theatre," says Bacon, "because all the systems of philosophy that have been hitherto invented, or received, are but so many stage-plays which have exhibited nothing but fictitious and theatrical worlds; and there may still be invented and dressed up numberless other fables of the like kind." Of this last remark, *Hutchinsonianism* may, in modern times, be regarded as an example, in common with all other speculations that have been opposed to the Newtonian theory of gravitation; and which will be found equally opposed to the method of science here recommend-

ed. It was strange that, in the eighteenth century, in the full blaze of that light which was, as it were, *latent* in the Baconian philosophy, and which Newton had struck out—a system, not unlike that of the *vortices* of Des Cartes, should offer once more to darken the heavens, after they had been so effectually purified from the *atoms* and the *plenums*, the *orbs* and the *cycles* of an imaginary astronomy: this, however, is but an example of the power which one favorite notion can exercise over an acute and ardent mind; for Hutchinson assumed, as the basis of his theory, that Divine Revelation was designed to teach men philosophy as well as religion; and in the Mosaic account of the creation, he fancied he saw the physics of the true astronomy. His system, however, which may be considered as a kind of physico-theological romance, has been permitted to sink into its merited oblivion, while revelation is now regarded as confined to its own sublime and proper province of making known the will of God to man, as to his conduct here, and the way of attaining felicity hereafter. The Newtonian philosophy cannot, on any consistent principles, be regarded as at variance with the communications of the Bible; and, founded as it is on the basis of *demonstration*, it cannot fail to stand the test of time. Gratuitous theories may impose on the imagination, like the *mirage* of the Egyptian sands; but, like this illusion, they must pass away: they may present to the eye a magnificence as gaudy and seducing as the *fata morgana*, sometimes witnessed on the coast of Calabria, in which the most beauteous landscapes, crowned with picturesque villages, superb palaces, and massy towers, seem to possess a real existence: all, however, is only suspended in the air, and the enchanted scene changes with the least shifting of the light, or the ruffling of the sea, melting away like a dream of the night—so must vanish at last all systems of philosophy and science that are not founded on the solid basis of that *induction*, which it is the design of the *Novum Organum* to explain.

This source of error and prejudice, or the *Idols of the Theatre*, are more especially to be marked as closely

connected with the *authority of great names;* and thus, not unfrequently, enslaving the understanding to an ignoble bondage, by what the schoolmen term *argumentum ad verecundiam*, or the argument addressed to the modesty of human nature. Prejudices of this kind stand on a different footing from the former three sources, and are perhaps the most remarkable instances of intellectual slavery. "For," says Lord Bacon, "the idols of the theatre are neither innate, nor are they secretly insinuated into the understanding, but are plainly forced upon it, and are received from fabulous theories and *false* laws of demonstration." The importance of returning to an independent and scientific method of inquiry, or, in other words, of thinking for ourselves, is urged by our author from the fact, that "a cripple in the right way may beat a racer in the wrong." The more vigorous, indeed, the mind is, which sets out in a wrong course, the further does it depart from the goal of truth and science. The method, however, which is here proposed, is adapted not merely to a subtile understanding, and a sublime order of faculties, but is level to the capacities of all, even the humblest. To draw a straight line, or to describe an exact circle, with the unassisted hand, might be a thing scarcely to be accomplished with certainty, whilst it is an easy task to do it by the help of a ruler and compasses, with the greatest accuracy. "All these idols," says Bacon, "are solemnly and forever to be renounced, and the understanding must be thoroughly cleared and purged of them; for the kingdom of man, which is founded in the sciences, cannot be entered otherwise than the kingdom of God—that is, in the condition of a little child."—In further illustration of these prejudices, *some notice* is proposed to be taken of the *sects* and *kinds* of these false theories; of their *outward signs and indications;* of the *causes* of this so great disadvantage to science; and of the reasons of so lasting and general a consent in error.

III. *Different Kinds of false Systems of Philosophy.*

The next topic of the *Novum Organum* relates to the *different philosophical theories* which have given rise to the last of the four classes of prejudices; or the *Idols of the Theatre*. Fanciful and imaginary systems of philosophy derive no small charm, it is well observed, from their being so highly wrought: thus, to many, the fictitious drama is more attractive than true history. Lord Bacon divides these visionary systems into *three* general kinds—*sophistical*, *empirical*, and *superstitious*.

Sophistical philosophies, so called from their deceitful pretences, are those formed on careless and hasty observations and experiments, and filled up by the mind of the inventor at his own pleasure. Of this kind Aristotle's philosophy is a very eminent instance, among the other ancient systems, which were chiefly of the sophistical kind. Even the *similar particles* of Anaxagoras, the *atoms* of Leucippus and Democritus, the *heaven and earth* of Parmenides, and other *first principles* of the different sects of Greece, with all their incongruity, at least savor somewhat of natural philosophy and experience: but Aristotle, both in his Physics and Metaphysics, utters little else than mere logical terms. Even in some of his other writings, where he makes greater use of experiment and observation, he appears to have passed a previous judgment on nature, and attempts to lead experience itself captive to his own opinions and his own humor: he forms a world of *categories* and *predicaments;* accounts for nature's varied operations by the scholastic distinction of *act* and *power;* asserts that there is but *one proper motion* in all bodies; and imposes numerous other fictions on mankind, which are sources of disputation rather than of truth.

Empirical systems are those formed upon a *few experiments only*, though these may be made with great exactness. The ancient chemists are adduced as examples, in their idle speculations on the four elements, founded on a few repeated experiments of the furnace. William Gilbert,

who lived in Lord Bacon's time, and framed, as we have remarked, a system of philosophy on his experiments in magnetism, was a notable instance of this kind.

Superstitious systems are those in which certain philosophical theories are blended with religion, and the one is made subservient to the other. Of these the philosophies of Pythagoras and Plato are specimens; their theories being principally derived from their speculations on the nature and attributes of the Deity. Some theories of the earth in modern times may come under this denomination; and perhaps there is no more signal instance of this kind than the philosophy of Mr. Hutchinson, which we have noticed above. "This vanity," says Bacon, "of mixing things divine with things human, is rather to be suppressed, as from it arise not only phantastical philosophies, but heretical religions."

In framing theories, the mind, it is observed, should be especially on its guard against two excesses, that of *dogmatism* on the one hand, and *scepticism* on the other, as these both tend to perpetuate prejudices, scarcely allowing the opportunity of their removal. Thus Aristotle, in order to cut off all occasion of doubting, invented questions, and resolved them at his pleasure, as if he were the arbiter and final judge of nature; while Pyrrho and his followers, on the contrary, doubted of every thing, which was an abuse of the school of Plato, where the sceptic method was first introduced by way of jest and irony, to oppose the more ancient dogmatists. The former of these methods, or that of positively dogmatising, cannot but contract and degrade the mind, while the other must cast it into languishment and despair of ever finding the truth.

All these *Idols* of the mind which have now been noticed, have moreover been greatly defended and strengthened by false *proofs* and *corrupt demonstrations*. Words have been the tyrants of thoughts, and thoughts the slaves of a conceited logic, which has been associated with erroneous and hasty impressions from the senses—ill-formed notions arising from these impressions, and faulty induction, or such a method of establishing general principles, as has been the

parent of all error, and the destruction of all the dignity and advancement of science. Thus it was that Gilbert limited his experimental inquiries to the loadstone; and the early chemists and their followers were perpetually employed in the single art of *alchemy*. This word means the knowledge of the *substance* or *composition* of any thing: and the two leading objects of the *alchemists* were, the change of the common into the precious metals, or gold and silver; and the discovery of a universal medicine—some elixir of immortality which they fondly hoped would annihilate disease, and prevent the irrevocable doom of humanity, death!

IV. *Characteristics of false Systems.*

Lord Bacon next gives some *intimations, or signs by which false theories and systems of philosophy may be known*, so as to prevent the impositions likely to arise from them.—One is, the *origin* from which a system of philosophy is derived; which, if it be false and erroneous, whatever immediately arises from it must of course be so too. The sciences existing in the time when the *Novum Organum* was written, were almost wholly derived from the Greeks, whose philosophy, as we have seen, was chiefly of the dogmatic and disputatious kind. This was the characteristic, generally, of their several schools; the writings of the more ancient of the Greeks, who opened no schools, having been lost in the lapse of time, such as those of *Empedocles*, *Anaxagoras*, *Leucippus*, etc., who applied themselves to philosophy with greater simplicity, and with less affectation and conceit, than their successors. The *source* of the existing philosophy was, therefore, corrupt.

If any indications may be gathered from the *times* in which the ancient theories were framed, no great good, it is further argued, could be expected from these. In the ages of the Grecian philosophy, the field of observation and experience was limited by the little knowledge the ancients possessed of the habitable world. Their history, also, of past events, and of the origin of nations, was to a great degree fabulous. They considered many regions uninhabita-

ble where great nations have been since found to exist. Their travels were extremely circumscribed, and the art of navigation was exceedingly imperfect.

If, moreover, we judge from the actual *effects* of the Grecian philosophy, very little can be shown to have resulted from it tending to improve the condition of mankind, during the space of so many ages. Something, indeed, may have accrued from the pursuit of chemistry among the ancients and their followers: but this has rather happened by accident than been produced by design; for all their theories were injurious to the discovery of truth. The cultivators of the magic arts, too, in their jugglery, have stumbled on some few matters; but even these have been corrupted by imposture. The *alchemists*, however, Lord Bacon allows, made not a few useful discoveries while vainly pursuing their chimerical and visionary projects. We are indebted to their labor and perseverance for the method of preparing alcohol, aqua-fortis, vitriolic acid, volatile alkali, gunpowder, and a variety of other chemical compounds.

Another test of truth in philosophical systems may be derived from their *progress* and improvement; but, up to the seventeenth century, that is, for two thousand years, the sciences had been nearly stationary; or, rather, they flourished most in the remotest ages, and afterwards declined. Witness the decay of the Pythagorean astronomy till the time of Copernicus.

Again, the *confession of the authors* themselves of the systems that had prevailed may be regarded as a testimony of the strongest kind to the vanity and inefficiency of these theories; for while these men pronounced on nature with the utmost confidence and dogmatism, we may detect them at intervals assuming a desponding air, and complaining of the obscurity and uncertainty of all things. Hence arose the school of the *Academic* philosophers, who doubted of every thing, and consigned mankind to the eternal darkness of a sceptical ignorance.

The great *disagreement* and *opposition*, moreover, that existed among the ancients, shows, says Bacon, that "the avenues from sense to reason were not well guarded, since

the one subject of philosophy was so rent and split into error, that nothing remained fixed and stable in the existing notions derived from the Greeks; nor was there any certain rule of investigation."

The opinion, also, that was entertained in the sixteenth century, that a *general consent* prevailed in the philosophy of Aristotle, was a *fallacious* argument of its truth; for the prevalence of the doctrines of Aristotle and Plato was greatly owing to the accidental circumstance of their being preserved from the general wreck of human learning, which ensued on the irruption of the barbarous nations into the Roman empire. Besides, such a consent as that which is supposed, if proved to be ever so little founded on accident, would better deserve the name of *obsequiousness;* not being the result of a free exercise of men's judgments, all centring at last in the same conclusion, but the offspring, as it is evident, of prejudice, and an abject vassalage to the authority of names.—The character, therefore, of the systems of science and philosophy that had been current, was extremely unfavorable to the supposition of their truth, whether taken from their *origin*, their *fruits*, their *progress*, the *confessions* of their authors, or from *general consent*.

V. *Causes of Error in Philosophy.*

The next topic of the *Novum Organum*, and the *fifth* convenient section into which the former part of the work may be divided, relates to the *causes of error* in philosophical inquiry.

The first cause assigned by our illustrious author is, the *short space of time* which, notwithstanding the lapse of so many ages, had been at all productive in the discoveries of science. He beautifully compares duration to space, and places before us the emblem of a barren desert, as a fit representation of that lasting sterility which had reigned over the tracts of time. Scarcely six of all the centuries preceding the age in which he lived could be regarded as, in any degree, exceptions to this general win-

ter of the human mind. The middle ages were proverbially periods of gross and palpable darkness. Men of leisure were found shut up in the gloom of monasteries; and rarely did a ray of genius emerge from these cloistered solitudes, and find its way into the theatre of human life, so as to improve and embellish it with inventions like those which have, in our happier times, rendered it a scene of ever new and increasing wonders.

Even at the best, the comparative *neglect* of the philosophy of *nature*, properly so called, may be regarded as another source of the slumber of the human intellect, and of its inefficiency in attaining to anything like a just method of science. The sublimest geniuses, allured by gain, or by the love of speculation, exhausted their energies in the disputes of a scholastic theology; or, at a more early period, among the Romans, were almost wholly devoted to politics. Mathematical and natural science, the parents of all mental discipline, had lost the footing they had obtained among the remoter Greeks, almost from the time of *Thales;* and even the great moralist, *Socrates*, had contributed, in a considerable degree, to turn away men's minds from the contemplation of nature. Thus the most definite and tangible sources of our knowledge—those which are peculiarly adapted to fix and regulate the operations of the mind, by perpetually recalling its attention to what is seen, and felt, and heard—were abandoned; and the human imagination was suffered to roam in a shadowy and aërial region, amid a scenery that was not nature's creation, but its own.

Again, where some taste for the study of nature herself *did* exist, scarcely one single individual was found to devote himself *wholly* to this pursuit. Nature was still not sought for her own sake, but was made the handmaid of some profession; and to this she was enslaved. Nature was not regarded as the parent of the sciences; and these, by standing too much alone, resembled the branches of a tree attempted to be kept alive separated from the root and the trunk.

The *true end* of science also was *mistaken*, "which," says Bacon, "is to enrich human life with useful arts and

inventions;" and philosophers had made it their chief object to be at the head of sects; to aggrandize their own fame; to gain dominion over the minds of men; or to obtain some other exclusively selfish end. Almost every kind of inferior aim was by turns the lord of the ascendant, while *truth*, immutable, unalterable truth, loved and sought for its own sake, was eclipsed, or cast into the shade.

Besides, had the end itself been right, yet the *method was wrong*. As this is the main drift of the first part of the *Novum Organum*, we can scarcely insist on it too much, since nothing is more important here than to remember, that so long as any gross impropriety exists in the *manner* of investigating truth, the most strenuous labor must be in vain. All things were left, as it is strongly expressed, "to the darkness of tradition; the giddy agitation and whirlwind of argument; the waves and windings of accident; and a vague, uninformed experience." The first inquiry had always been, to know what others had said and thought on the given subject. This was usually received, and to it were added the vagaries of the inquirer himself. Such a method could, of course, only propagate and perpetuate error; and in such a state of things truth still remained shut up as in a labyrinth.

The blind reverence for antiquity, also, which had possessed the minds of men, and the devotedness which existed to great names, well accorded with the feeble efforts of the human intellect, and formed a striking feature in the reign of darkness. The assertion of a philosopher was almost the only specific against error, and the chief support of truth; whereas, observes Lord Bacon, "truth is justly to be called the daughter, not of authority, but of time;" in other words, time and patience alone can furnish the opportunity of that observation and experiment on which knowledge must be legitimately founded. The argument addressed to human modesty, as the logicians termed it, was, however, often received with a kind of religious awe, even when the proposition affirmed, if, indeed, understood at all, was revolting to common sense. It certainly ought to be no subject of complaint, that this is the peculiar de-

linquency of the age in which we live. Even the overpowering genius of Newton has not preserved his theory from opposition in very recent times—an opposition, nevertheless, only to be viewed as the result of that most desirable freedom of inquiry, which was almost unknown to the ancients, and which can at no period issue in anything but the additional, or, we might say, the superfluous, confirmation of the Newtonian philosophy. To believe without examination, however it may accord with our natural indolence, is unworthy of the mind of man. In such an assent, its noblest powers are more than dormant and useless: they contract, if we may so say, by every such repetition of what is not worthy to be called *belief*, a sort of rust and stiffness, that unfits them entirely for all original and unbiased inquiry, and which ends only in rivetting the chains of ignorance and error.

Similar in its effect to the admiration of great names, is the *tendency to be dazzled* with whatever rises, in the least degree, above the ordinary level in the productions of the human mind. Too much satisfaction and complacency in what has already been attained may have the effect of obstructing further progress. This, Lord Bacon observes, has particularly shown itself in the inventions of the mechanic arts. We are, perhaps, more ready to rest in an empty admiration of what has been effected, and to amuse ourselves with the apparent opulence of human power, than to reflect on the little progress that has been made in bringing matter under our control, and to consider the vast field that still lies open before us. After all, in mechanical instruments, the ultimate principle is very *simple*—all may be reduced to a few laws of nature. In a clock, for instance, which seems, in one view, to imitate the movements of the heavenly bodies, and in another, to resemble the pulsations of animals, by its regular and successive motions, a few principles only are ultimately employed, as the law of pendulums, depending chiefly on gravitation. With what sentiments, however, would the ancients have looked on such an invention as the steam-engine, in which, nevertheless, the whole of the novelty, strictly speaking, lies in the ap-

plication of the expansive power of steam! The causes of retardation in the improvement of knowledge, dwelt on in this part of Lord Bacon's work, have certainly been counteracted, in our time, by that rapid succession of inventions which has marked the increase of the sciences, though, in other respects, there would be much more to foster the complacent admiration he speaks of.

Another considerable cause of error and ignorance to the world, is placed, by this most accurate observer, in the *pedantry* of philosophers themselves, who have contrived to impose on mankind by their pompous airs, and affected manner of teaching—by the trickery of a meretricious and bombastic oratory, and by the subtile divisions and definitions they have employed; so as to inspire the vulgar with a profound idea of their wisdom, and to leave the impression that the sciences were exhausted by their learned labors, and nothing remained now to be investigated. No doubt this has, in every age, been a fertile source of obstruction to human improvement. The most dignified, and even sacred professions have been too often degraded by a conceit and a quackery which, while it has disgusted the discerning, as the subterfuge of incompetent effrontery, and has proved an injurious bar to the exertions of modest and genuine merit, and to the progress of pure truth, has not failed to gain its own selfish ends, in the plaudits of an ignorant multitude. The only cure for this evil is the general diffusion of knowledge among all classes of society, which is, most happily, a leading feature of the present illustrious times.

The ancient and erroneous systems of philosophy obtained an additional hold on the public mind, also, in consequence of the *vanity* and the extravagant *pretensions* of not a few individuals of more modern date. Lord Bacon had to encounter this disadvantage in the very enunciation of many of the topics of inquiry to which he desired to recall the attention of the world in a just and scientific method: we allude to his notices for increasing men's acquaintance with the mineral kingdom; for obtaining more information with regard to the winds and the weather; the means of

prolonging human life, and other inquiries. He complains of the weakness and imposture of many who had amused the credulity of mankind with great promises, in reference to such topics as the retardation of old age—the relief of pain—cures for the deceptions of the senses—the method of exciting the affections by sympathy, or a species of animal magnetism—the exaltation of the intellectual faculties—the transmutation of substances, as professed by the alchemists—the procuring of celestial influences—divination of future events—the revealing of secrets—and other such like conjuring. Thus, as real history may sometimes have suffered in its credit from fiction,—and there are some who would consign the conquests of Julius Cæsar to the same scale of probability with the fabled exploits of Arthur of Britain, or Amadis de Gaul,—so the spirit for great designs has been quenched by the dread of what might prove chimerical and romantic, and men have been contented to repose in the solemn and received dogmas of antiquity.

"So great, moreover," adds Lord Bacon, "has been the pusillanimity and indolence of men, that they have been wont to satisfy themselves with *very slender performances;*" often exalting with the title of new mechanical inventions, what were, in fact, nothing more than some trifling modifications of old ones—this has been another barrier, he considers, to the advancement of the sciences.

But one of the most formidable obstacles to the genuine knowledge of nature is to be found in the *superstition* which has mingled itself with the great and momentous subject of religion. We learn from Aristophanes, in his play of "*The Clouds*," that among the Greeks, those who first attempted to assign the natural causes of thunder and storms were condemned as the enemies of the gods. Nor did some of the early Christian fathers, as our author remarks, meet with much less severe anathemas for daring to assert, on the evidence of infallible proof, the spherical figure of the earth, and the existence of *antipodes*, or people at the other side of the globe, whose feet are opposite to ours. It is known to most of our readers that Galileo, the inventor of the telescope, was consigned to the dungeons of

the inquisition at Rome, for the crime of asserting the motion of the earth round its own axis, and was condemned to do penance, by repeating once a week the seven penitential psalms for the space of three years!—The blending of the scholastic and Aristotelian philosophy with religion, in the middle ages, was a fruitful source of this kind.

Lord Bacon's remarks on this subject are so just, and so important, that we shall quote him at length. "As things now are," he says, "it is still more difficult and dangerous to discourse on nature, on account of the summaries and methods of the scholastic divines, who have, with all their might, reduced theology to order, and fashioned it into an art; and have, moreover, blended too much of the disputatious and thorny philosophy of Aristotle into the body of religion. And to this subject, though in a different respect, belong the labors of those who have ventured to deduce and confirm the truth of Christianity from the principles and authority of philosophers; celebrating with great pomp and solemnity the intermarriage of faith and sense, as a lawful union, and soothing the minds of men with a grateful variety of matter, while at the same time they have rashly and incongruously mingled things divine with human. In such medleys, moreover, of divinity and philosophy, only those things are admitted which are *now* received in philosophy, whilst things that are new, though better than the old, are almost entirely excluded. In fine, we perceive, that, through the ignorance of certain divines, the passage to any philosophy, though ever so true, is almost blocked up. For some are foolishly alarmed lest a deeper inquiry into nature should transgress the bounds of sobriety; and they injudiciously wrest what is said in Scripture against those who pry into divine secrets, and apply it to the hidden things of nature, which are nowhere forbidden. Others, with greater craft, imagine, that if men are kept in ignorance, all things may be the more easily managed by dexterity of hand, and the *divining rod*, which they think is highly serviceable to religion: this, however, is nothing else than to aim at pleasing God by a lie! Others, again, dread the effect of example, lest any changes and move-

ments in philosophy should fall at last on religion itself. Others are afraid lest, in the inquiry into nature, something should be found which may overturn religion, or at least undermine it, especially among the ignorant. These two latter kinds of fear appear to me altogether to savor of a grovelling wisdom; as though men, in their secret thoughts, were doubtful and distrustful of the stability of religion, and of the power of faith over the senses, and on this account apprehend danger to it from the search after truth in natural things. But whoever considers aright will acknowledge, that, next to the word of God, the most certain cure of superstition, and the best aliment of faith, is the knowledge of nature. Therefore philosophy is given to religion as her most faithful handmaid; the one manifesting the will, the other the power, of God: nor did he mistake who said, 'Ye err, not knowing the Scriptures, and the power of God,' thus inseparably blending and joining together the knowledge of his will, and the contemplation of his power. In the mean time, it is less to be wondered at that the increase of natural knowledge has been restrained, when religion, through the ignorance and incautious zeal of some, has been set in opposition to it."

The *customs of learned societies* had also, up to the time of Lord Bacon, proved a serious hinderance to the advancement of knowledge. In the schools and universities of Europe, scarcely any room was given for improvement, which was branded with the invidious name of innovation, an alarm that could not but prove fatal to the interests of pure truth. If any one dared to exercise the right of judging for himself, he could hope for no encouragement from others; and if he possessed sufficient independence of mind to stand alone, he must pay for his temerity with the loss of his fortune and his good name. All was rigidly confined within certain rules, and a given track was marked out as that in which every one must go without deviating either to the right or left. Little scope was afforded to the power of genius, which could hardly expand upwards beneath the overwhelming load of scholastic prejudice that weighed it down. Perhaps even in our own enlightened age, few of

the universities of Europe are entirely emancipated from these shackles, as may be seen from the tendency there has always been to adhere to an *Aristotelian division* of the sciences, instead of following nature. "Unwilling as I am," says Mr. Stewart, at the close of his second volume on *The Philosophy of the Human Mind*, "to touch on a topic so hopeless as that of academical reform, I cannot dismiss this subject without remarking as a *fact*, which at some future period will figure in literary history, that two hundred years after the date of Bacon's philosophical works, the antiquated volume of study, originally prescribed in times of scholastic barbarism, should in so many universities be still suffered to stand in the way of improvements, recommended at once by the present state of the sciences, and by the order which nature follows in developing the intellectual faculties."

Lord Bacon also complains that in his time arduous endeavors at improvement were *not rewarded*. The power of advancing knowledge must proceed from the energies and exertions of superior minds, but the rewards which sweeten labor were in the hands of the vulgar and untutored. Even the boon of praise was, he observes, withheld, since the flights of elevated minds are above the reach of the crowd, and are disregarded through the force of prevailing prejudices.

Finally, science was kept in bondage by a kind of sullen *despair of success*, and the supposition of impossibility attaching to any new endeavors. Such are the causes assigned in the *Novum Organum* as the principal sources of continued error and uncertainty in the pursuits of knowledge and science.

VI. *Grounds of Hope regarding the Advancement of Science.*

In that division of the work which we may call the *sixth* section, our author proceeds to treat of the *grounds of hope* for the further advancement of the sciences, and the general improvement of knowledge. Thus the *improvement*

in navigation was to be regarded as the harbinger of good to the sciences, as enlarging the field of observation, and tending to increase our knowledge of nature.

The very *errors of past times*, likewise, properly viewed, furnished a hope of amendment. Demosthenes endeavored to rouse the Athenians from despondency to arm themselves manfully against Philip, their great enemy, by telling them that even their past misfortunes should be regarded as an omen of their future success, since they arose from their own negligence; whereas, if they had strenuously exerted themselves, and had still been unsuccessful, they might justly have despaired of the future: so, in the sciences, it would have been presumptuous to expect any great improvement, if we could have supposed mankind to have travelled so long in the proper road to truth without reaching it; but as they had evidently mistaken the way, hope of future success must be sought in first returning to the right path. The true method of science is ingeniously compared to the economy of the bee, which first gathers matter from the fields and gardens, and then digests and prepares it for use by her own native powers: "so," Lord Bacon observes, "the matter of philosophy must be carefully collected from nature, and then, after being digested and elaborated in the understanding, must be treasured up in the memory;" in other words, additional hope of advancement in the sciences is to be found in the union of things that had been disjoined; that is, a strict *combination of experience with calculation and reasoning*. In all the schools of Greece, natural philosophy was blended with some foreign admixture, and was never studied purely and by itself. The Aristotelians corrupted it with a perversion of logic; the school of Plato mixed it up with an imaginative theology; the second school of Plato, Proclus, and others, made it to arise out of mathematics; whereas it is justly remarked that mathematics ought "not to generate or create natural philosophy, but only to terminate and perfect it;" that is, the facts and laws of nature must be sought independently, or in Nature herself—then mathematical reasoning may be applied to estimate and measure

them, as has been exemplified in several of the tracts already before our readers. A return to the study of natural philosophy in a *pure and separate form*, was another source, therefore, of hope.

So also it might be expected that in future *some philosopher* might arise of sufficient independence of mind and lofty genius to free himself and the world from all the old and hackneyed theories: such a person, it is lamented, had not then appeared. How prophetic this was of the immortal Newton, who burst upon the world almost immediately after the death of Bacon, his forerunner, and how completely he emerged from the rude and undigested chaos of ancient fables into the light of truth, as those very comets whose laws he laid down issue from the dark abysses of space to their perihelion, the reader is sufficiently aware.

Much, very much, is also augured, as likely to arise from a better *history of nature* than had as yet been collected. The accounts which had been extant of the appearances and facts in nature had been chiefly founded on popular reports, indolent observations, and often on mere idle tales; and the whole had been so framed and turned as to strengthen the existing opinions in philosophy. Almost every thing in the history of nature was undefined and vague; much good must, therefore, needs have been expected to accrue from a more accurate register of facts and experiments. Bacon exhibits a rough sketch of such a history of nature in his *Sylva Sylvarum*, in his *Tables*, and in other parts of his works; the merits and defects of which we shall have occasion to notice hereafter.

Similar advantage was to be anticipated from a more enlarged stock of *mechanical experience*, and a more enlightened attention to the most instructive facts of this kind. The workman is apt to think only of what is useful to his immediate work, and is not concerned about the discovery of truth: but, in order to improvement, recourse must be had to experiments, which, though useless, perhaps, as to direct and immediate profit, may be of great importance as to general information.

To this larger and more accurate stock of experience,

22 *

Lord Bacon again insists, must be added the *method of induction;* or, as before explained, the pursuit of knowledge by reasoning from particulars to generals, from which every thing is to be hoped. In order to render this method as efficient as possible, it is strongly recommended accurately to commit to writing all the materials of philosophy, that is, the facts and observations on which general principles are to be founded; by no means trusting them, as had too often been done, to the memory, whose defects were usually supplied by a fanciful invention. To give this method still greater perfection, it is remarked that *tables* should be used for the clear arrangement of the facts, according to the nature of the subject; and from these tables *axioms*, or general principles, should be carefully formed, gradually rising from the less to the more general. It must be acknowledged, indeed, that many discoveries had been made accidentally by the alchemists, while seeking to make silver and gold; yet it is evident that more is to be expected in inventions from industry and method, whether we consider the number of such discoveries, the saving of time, or the adaptation of the things discovered to the supply of our wants. Men are more likely to find what they are carefully and intelligently in search of, than what is left merely to the operation of blind chance.

It was to be regarded as an additional ground of hope that *some things* already discovered were such as had previously never entered the mind of man; or which would, in all probability, have been despised as impossibilities, if any one had declared them likely to be found out. Gunpowder, though a destructive invention truly, may be taken as an instance. If, before this discovery had been made public, it had been declared that there was a method of battering down walls, and making an impression on the strongest fortifications at great distances, those who heard of it would instantly have supposed that this was effected by increasing the power of the common engines of war that were previously in use, as battering rams, and other machines of the same kind; which, of course, must be done by means of additional weights, wheels, and levers,

and the various combinations of the mechanical powers; "but no one," says Bacon, "would have thought of a fiery wind which should blow with such a prodigious expansive violence, no obvious examples of such effects having been previously seen, except in the sublimer operations of nature, storms, thunder, and earthquakes, which it would not be supposed were imitable by art." Perhaps, to the ancients, the expansive force of steam, now so extensively employed, would scarcely have appeared less wonderful, which, while it possesses such amazing power as to produce the most terrible effects when allowed to explode by being confined, is yet capable of being regulated at pleasure, and directed to an immense number of useful works with the greatest advantage. The invention of silk is mentioned as another example. So, likewise, if, previously to the invention of the compass, it had been said that a certain instrument should be made known, which, in the open sea, and in the dead of night, when neither stars nor moon appeared, would exactly point out the quarters of the heavens, and that this instrument was nothing more than a metallic substance, which might easily be overlooked among the similar productions of the earth, this would have seemed almost incredible. Whence it is argued that many other things may yet remain in nature that might be of great service to mankind, which have little relation or analogy to the things already discovered.

Again, on the other hand, there are inventions of such a kind as easily to be *overlooked* for want of method, though they may almost, so to speak, stare men in the face. While some things, as gunpowder, silk, the compass, sugar, paper, may seem to depend on certain properties to be developed by Nature herself, yet other things, the art of printing, for instance, contains nothing that is not obvious and completely within human power; nevertheless, the world was for many ages destitute of this admirable invention, which is so intimately connected with the propagation of knowledge. Hence a ground of hope that science might be improved was to be drawn, not merely from the consideration of the unknown operations of nature

hereafter to be discovered, but from the probable result of transferring, compounding, and variously applying those laws and operations which were already known.

Lord Bacon also derived encouragement from reflecting on the immense expenditure of time, genius, and property, that had been bestowed on *pursuits of little or no use*, alluding, probably, to alchemy, the professed magic arts, astrology, etc.; since, if but a small portion of this labor should come to be bestowed in a proper manner, and on proper objects, great things might be expected to result: especially would such extensive and laborious *histories* of the *facts* and *operations* of nature as he recommended be the source of expectation. "A great and royal work truly this," he says, "and of much labor and expense."

As a further ground to suppose that human knowledge might be improved and increased to an extent of which some were inclined to despair, Lord Bacon introduces *his own example*, "not," he modestly says, "by way of ostentation, but because it may be useful." He argues, that if he himself—a man as much employed in civil affairs as any other of the age in which he lived, for he was Lord Chancellor of England at the time his *Novum Organum* was published;—if he, a man of but infirm health, has had the honor to lead the way unassisted by any coadjutor, in the new and untrodden path which he here attempts to point out to posterity; what may not be expected from men of leisure; from a union of labors; from a proper division of them, and from opportunities afforded by the succession of ages? He concludes his remarks on the grounds on which is founded the hope of advancing the sciences, by intimating that even were this expectation much less than he rightly deemed it to be, or, to use his own language, "although a much weaker and fainter breeze of hope should breathe from *this new continent*," or world of science, which he is endeavoring to point out; yet it would be worth men's while, at all events, to make efforts to explore nature by the light of this new method: there was, at least, *a chance* of success resulting from their labor; whereas, to sit down in despondency, and to decline all

enlightened exertions, could lead to nothing but ignorance and error, and was unworthy of the dignity of the human mind

VII. *Further Remarks preparatory to the Inductive Method.*

The last or seventh section into which this former part of the Novum Organum may be divided, is designed to give *some further idea of the new method here proposed of interpreting nature.* This, however, is done rather by way of guarding the reader against erroneous expectations than by developing the method itself, which he reserves for the second part. "Having now levelled and polished the mirror," says our author, in his figurative and expressive diction, "it remains that we set it in a right position, or, as it were, with a benevolent aspect towards the things we shall further propose. For to a new undertaking, not only a prepossession in favor of a rooted opinion is prejudicial, but a false notion and imagination of what is proposed to be done is equally so. We must, therefore, endeavor to convey a just and true idea of what we intend."

In order to prevent misapprehension, he again cautions his readers, as he had done at the outset of his work, against supposing that he aspired to be the founder of a *new sect* in philosophy, after the manner of the ancient Greeks. It was his aim, and it was an aim worthy of such a master-spirit, not to reign over men's opinions, but to conduct them into the temple of truth, from whose inmost sanctuaries they might obtain such a panoply as would enable them to extend the boundaries of man's power over nature, not in the noisy triumphs of a scholastic warfare, but in glorious victories over ignorance, prejudice, and error. Though he thus disclaims the idea of attempting to found a new sect, it must be allowed that he possesses that honor in the highest sense; for if we were, in the most general manner, to designate the philosophers of modern times, in contradistinction to the Aristotelians and Platonists of an earlier period, we should call them *Baco-*

nians: Bacon may himself very justly be accounted the father of the modern philosophy. He, however, contents himself here with aspiring, as he says, "only to sow the seeds of pure truth for posterity, and not to be wanting in his assistance to the first beginning of great undertakings."

Lord Bacon wishes his readers, in perusing his work, not to be prejudiced against the method he recommends, nor disappointed on finding that he has not made any very striking *discoveries*, which, indeed, he does not profess to have done; his design, in fact, being obviously of a more general nature. For though in the *Novum Organum*, and in his other works, indications and outlines of discovery are to be found, yet he considered that, up to his time, there was no sufficient collection of facts and appearances, to enable any one to enter with advantage on the genuine interpretation of nature. Still he did not wish to discourage any from employing their sagacity in attempting to make discoveries on the foundation of what was already known, or from making use of his own tables and outlines of a history of nature, to this end; but his own great object, he repeats, was to prepare the way for future improvements, and not to neglect this his main design, for the sake of hasty and unseasonable diversions, like "Atalanta" in the fable, who lost the race by stopping to pick up the golden apple. "For we do not childishly affect golden fruit, but place every thing in the victory of art over nature."

He next cautions the reader against the effect which may be produced on his mind from meeting with some experiments in the *history* of nature, and *tables* of invention, which seem *not* well *verified*, or which may even be absolutely *false*. Such errors are to be expected to creep in at the dawn of the day of Science, and Lord Bacon was certainly by no means free from them. It must not, on account of a few such oversights, be suspected that the inventions he would point out are grounded on doubtful principles and erroneous foundations; and he argues that if any should be disgusted with some particular mistakes in his account of facts in nature, what must be thought of

the remiss and negligent method that had hitherto been employed, and what of the philosophy and of the sciences that were built upon such "quicksands?"

Nor are men to turn away from the inductive method, or from the experiments it demands, as if in some cases it dwelt too much on what might seem *minute*, or *trite* and *vulgar;* since great mischief has arisen from many things having been spoken of as known and ascertained, of which, in fact, little was understood. Thus, in the philosophy that was prevalent, *gravity*, the *celestial motions*, *heat*, *cold*, *hardness*, *fluidity*, *density*, *animation*, *similarity*, *organization*, were all the subjects of dogmatic assertion, while little that was satisfactory was said respecting them. Men, however, must condescend to attend to the commonest things if they would acquire knowledge, and to things displeasing to the senses. The design here is "not," he says, "to build a capital or erect a pyramid to the glory of man, but to found the temple of the universe in the human intellect." None are to suppose, what the vulgar are too ready to imagine, as well as all who were devoted to the existing philosophy, that the minutiæ here laid down are tedious and subtile; they ought rather to consider that, for a time, efforts should be made to increase the materials of knowledge, to kindle the light by which nature may be examined, and that a too great impatience for immediate advantage should be checked. If any one should be inclined to disregard the cautions, principles and axioms laid down in the method of induction, as needless subtilties, what would he say to the schoolmen, who are full of subtilties, "without end as without fruit?"

As an apology for what to many would appear a *bold* and *daring* attempt—that of rejecting all the sciences, and all the ancient masters in philosophy as with one stroke, without admitting the authority of any one single renowned name of antiquity, and trusting only to his own unaided strength—the author remarks that, were he disposed to act insincerely, it would not be difficult to persuade men that what he here attempts is but a revival of the most ancient method of science, before nature was pompously ushered

in with the "flutes and trumpets of the Greeks;" and, well acquainted as Lord Bacon was with the mythology of the ancients, it would have been easier, perhaps, for him to have gained over the admirers of antiquity by this expedient, than to render palatable a system which presented no gaudy and alluring theories, and which came out entirely as a modern innovation. But with that astonishing degree of freedom from the shackles of prejudice, considering the time in which he lived, and that devotedness to natural truth for its own sake, which was so characteristic of this great philosopher, he disdains all such "stratagem and imposture," and relies exclusively on the evidence of things themselves. It is his object to place before the mind, not the mock models of the world which others had framed, of which the theories of Aristotle, Plato, and Epicurus, are specimens, but to present the world's true model as it exists in nature—to trace before the eyes of men the exaet lines of truth.

Another objection, which it is supposed may be alleged, is, that, notwithstanding all the labor here employed to impress on mankind this new method of studying the sciences, it will probably do no more than land us at length in *some one of those systems* of philosophy which prevailed among the ancients—that they, in the beginning of their investigations, procured a large stock of observations and experiments, and digested them into books and tables, as is here recommended, and from these sources extracted the matter of their theories; but thinking it needless to publish their notes and minute observations, those materials of their labors are now lost to us,—as architects, after a building is finished, take down the scaffolding and framework, and remove them out of sight. To this it is answered, that though it is difficult to suppose the ancients completed their works without some such collection of materials, yet, at all events, it is certain, from their writings, that their method of philosophizing was no other than flying hastily from some particular examples to general conclusions; and if any new examples occurred, bearing an aspect hostile to their favorite ideas, they either contrived to make them seem

to square with these, or else struck them out as exceptions, thus sacrificing every thing to their beloved theories. Now the very method here insisted on, Bacon argues, of rigidly adhering only to those principles which are common to all the particulars and examples, precludes the possibility of arriving at the same results with the ancients.

Nor can it be fairly charged upon this method of carefully attending to all the facts of the case before drawing the conclusion, that it leads to *scepticism*, since it is not the disposition to doubt, but the art of *doubting properly*, that is alone inculcated; and it is preferable to know something in a certain manner without supposing we know all, than to think we know all, and yet remain in actual ignorance of that which is most necessary to be known.

Lest it should be supposed, moreover, that the proposed plan only extended to the improvement of *natural* philosophy, more properly so called, he distinctly informs his readers that his design is of the most general kind possible. The method of induction is equally useful in all the sciences. It is alike applicable to *ethics*, *politics*, the *philosophy* of the *human mind*, *chemistry*, *botany*, and every other branch of knowledge.

As a further stimulus to a vigorous pursuit of science in this enlightened method, this first part of the *Novum Organum* closes with a few additional reflections. It is urged that the discovery of *truth*, and noble inventions, holds the most *excellent* place among the actions of mankind. Antiquity, with all its errors, was perfectly alive to this sentiment, as is sufficiently evident by its attributing *divine* honors to the inventors of the arts, as to Prometheus, who is represented as being the giver of fire to mortals, and is celebrated in Æschylus as a deity—while it was usual to award *heroic* honors chiefly to mere legislators and the founders of empires. The inventions of science, it is observed, "benefit mankind to the end of time; while the advantages conferred by warriors and statesmen may last, in many cases, but for a few ages, and sometimes have their origin in tumults, and the most terrible desolations of war." The effects of the invention of printing and

of the mariner's compass, for example, have been altogether prodigious: by these great instruments, navigation and commerce have been extended over the whole earth; "divine and human learning," to use the words of Milton, "have been raked out of the embers of forgotten tongues," and the face of the world has been changed, in all its features, physical and moral.

The design of promoting the advancement of the sciences is further pronounced a far *nobler* object of *ambition* than either *private* aggrandizement, or even *patriotism* itself. "The first," says Lord Bacon, "is vulgar and degenerate; the second, that is, the ambition of those who endeavor to raise their own country in the scale of nations, is more noble, but has not less of cupidity: but if any one should labor to restore and enlarge the power and dominion of the whole race of man over the universe of things—this kind of ambition, if so we may call it, is without doubt more wise and dignified than the rest. Now this power of man over things is entirely founded in arts and sciences."

"Finally," adds this illustrious author, "should any one object that the arts and sciences may be abused to *evil* purposes, as luxury and wickedness, let this sentiment be allowed to have no weight. The same objection would equally apply to all the most excellent things in the world —as genius, courage, strength, beauty, riches, and even light itself. Let the human race regain their dominion over nature, which belongs to them by the bounty of their Maker, and right reason and sound religion will direct the use."

Thus did this vast genius point out to mankind the causes of those errors which so long effectually obstructed the paths of science; thus did he encourage them to hope for a brighter æra, and give directions for the more successful pursuit, in future, of knowledge and truth. The second part of the *Novum Organum* contains a further developement of the principles of the *Inductive Method*, with the author's own examples of its use: and it will form the subject of another Treatise.

THE

GENERAL NATURE AND ADVANTAGES

OF

THE STUDY

OF THE

PHYSICAL SCIENCES.

FROM A PRELIMINARY DISCOURSE ON THE STUDY OF NATURAL PHILOSOPHY.

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CHAPTER I.

OF MAN, REGARDED AS A CREATURE OF INSTINCT, OF REASON, AND SPECULATION.—GENERAL INFLUENCE OF SCIENTIFIC PURSUITS ON THE MIND.

(1.) The situation of man on the globe he inhabits, and over which he has obtained the control, is in many respects exceedingly remarkable. Compared with its other denizens, he seems, if we regard only his physical constitution, in almost every respect their inferior, and equally unprovided for the supply of his natural wants and his defence against the innumerable enemies which surround him. No other animal passes so large a portion of its existence in a state of absolute helplessness, or falls, in old age, into such protracted and lamentable imbecility. To no other warm-blooded animal has nature denied that indispensable covering, without which the vicissitudes of a temperate, and the

rigors of a cold climate, are equally insupportable; and to scarcely any has she been so sparing in external weapons, whether for attack or defence. Destitute alike of speed to avoid, and of arms to repel, the aggressions of his voracious foes; tenderly susceptible of atmospheric influences; and unfitted for the coarse aliments which the earth affords spontaneously during at least two thirds of the year, even in temperate climates,—man, if abandoned to mere instinct, would be of all creatures the most destitute and miserable. Distracted by terror, and goaded by famine; driven to the most abject expedients for concealment from his enemies, and to the most cowardly devices for the seizure and destruction of his nobler prey, his existence would be one continued subterfuge or stratagem; his dwelling would be in dens of the earth, in clefts of rocks, or in the hollows of trees; his food worms, and the lower reptiles, or such few and crude productions of the soil as his organs could be brought to assimilate, varied with occasional relics, mangled by more powerful beasts of prey, or contemned by their more pampered choice. Remarkable only for the absence of those powers and qualities which obtain for other animals a degree of security and respect, he would be disregarded by some, and hunted down by others, till, after a few generations, his species would become altogether extinct, or, at best, would be restricted to a few islands in tropical regions, where the warmth of the climate, the paucity of enemies, and the abundance of vegetable food, might permit it to linger.

(2.) Yet man is the undisputed lord of the creation. The strongest and fiercest of his fellow-creatures,—the whale, the elephant, the eagle, and the tiger,—are slaughtered by him to supply his most capricious wants, or tamed to do him service, or imprisoned to make him sport. The spoils of all nature are in daily requisition for his most common uses, yielded with more or less readiness, or wrested with reluctance, from the mine, the forest, the ocean, and the air. Such are the first fruits of reason. Were they the only or the principal ones—were the mere acquisition of power over the materials, and the less gifted

animals, which surround us, and the consequent increase of our external comforts, and our means of preservation and sensual enjoyment, the sum of the privileges which the possession of this faculty conferred, we should, after all, have little to plume ourselves upon. But this is so far from being the case, that every one who passes his life in tolerable ease and comfort, or, rather, whose whole time is not anxiously consumed in providing the absolute necessaries of existence, is conscious of wants and cravings, in which the senses have no part, of a series of pains and pleasures totally distinct in kind from any which the infliction of bodily misery, or the gratification of bodily appetites, has ever afforded him; and if he has experienced these pleasures and these pains in any degree of intensity, he will readily admit them to hold a much higher rank, and to deserve much more attention, than the former class. Independent of the pleasures of fancy, and imagination, and social converse, man is constituted a speculative being; he contemplates the world, and the objects around him, not with a passive, indifferent gaze, as a set of phenomena in which he has no further interest than as they affect his immediate situation, and can be rendered subservient to his comfort, but as a system disposed with order and design. He approves and feels the highest admiration of the harmony of its parts, the skill and efficiency of its contrivances. Some of these, which he can best trace and understand, he attempts to imitate, and finds that, to a certain extent, though rudely and imperfectly, he can succeed,—in others, that, although he can comprehend the nature of the contrivance, he is totally destitute of all means of imitation; while in others, again, and those evidently the most important, though he sees the effect produced, yet the means by which it is done are alike beyond his knowledge and his control. Thus he is led to the conception of a Power and an Intelligence superior to his own, and adequate to the production and maintenance of all that he sees in nature,—a Power and Intelligence, to which he may well apply the term infinite, since he not only sees no actual limit to the instances in which they are manifested,

but finds, on the contrary, that the farther he inquires, and the wider his sphere of observation extends, they continually open upon him in increasing abundance, and that, as the study of one prepares him to understand and appreciate another, refinement follows on refinement, wonder on wonder, till his faculties become bewildered in admiration, and his intellect falls back on itself in utter hopelessness of arriving at an end.

(3.) When, from external objects, he turns his view upon himself, on his own vital and intellectual faculties, he finds that he possesses a power of examining and analysing his own nature to a certain extent, but no farther. In his corporeal frame, he is sensible of a power to communicate a certain moderate amount of motion to himself and other objects; that this power depends on his will, and that its exertion can be suspended or increased at pleasure within certain limits; but *how* his will acts on his limbs, he has no consciousness; and whence he derives the power he thus exercises, there is nothing to assure him, however he may long to know. His senses, too, inform him of a multitude of particulars respecting the external world, and he perceives an apparatus by which impressions from without may be transmitted, as a sort of signals, to the interior of his person, and ultimately to his brain, wherein he is obscurely sensible that the thinking, feeling, reasoning being he calls *himself*, more especially resides; but by what means he becomes conscious of these impressions, and what is the nature of the immediate communication between that inward sentient being, and that machinery, his outward man, he has not the slightest conception.

(4.) Again, when he contemplates still more attentively the thoughts, acts and passions of this his sentient, intelligent self, he finds, indeed, that he can remember, and, by the aid of memory, can compare and discriminate, can judge and resolve; and, above all, that he is irresistibly impelled, from the perception of any phenomenon without or within him, to infer the existence of something prior, which stands to it in the relation of a *cause*, without which it would not be; and that this knowledge of causes and their

consequences is what, in almost every instance, determines his choice and will, in cases where he is nevertheless conscious of perfect freedom to act or not to act. He finds, too, that it is in his power to acquire more or less knowledge of causes and effects, according to the degree of attention he bestows upon them, which attention is again, in great measure, a voluntary act; and often, when his choice has been decided on imperfect knowledge or insufficient attention, he finds reason to correct his judgment, though perhaps too late to influence his decision by after consideration. A world within him is thus opened to his intellectual view, abounding with phenomena and relations, and of the highest immediate interest. But while he cannot help perceiving that the insight he is enabled to obtain into this internal sphere of thought and feeling, is in reality the source of all his power, the very fountain of his predominance over external nature, he yet feels himself capable of entering only very imperfectly into these recesses of his own bosom, and analysing the operations of his mind,—in this, as in all other things, in short, "*a being darkly wise;*" seeing that all the longest life and most vigorous intellect can give him power to discover by his own research, or time to know by availing himself of that of others, serves only to place him on the very frontier of knowledge, and afford a distant glimpse of boundless realms beyond, where no human thought has penetrated, but which yet, he is sure, must be no less familiarly known to that Intelligence which he traces throughout creation, than the most obvious truths which he himself daily applies to his most trifling purposes. Is it wonderful that a being so constituted should first encourage a hope, and by degrees acknowledge an assurance, that his intellectual existence will not terminate with the dissolution of his corporeal frame, but rather that, in a future state of being, disencumbered of a thousand obstructions which his present situation throws in his way, endowed with acuter senses, and higher faculties, he shall drink deep at that fountain of beneficent wisdom for which the slight taste obtained on earth has given him so keen a relish?

(5.) Nothing, then, can be more unfounded than the ob-

jection which has been taken *in limine*, by persons, well meaning perhaps, certainly narrow-minded, against the study of natural philosophy, and, indeed, against all science,—that it fosters in its cultivators an undue and overweening self-conceit, leads them to doubt the immortality of the soul, and to scoff at revealed religion. Its natural effect, we may confidently assert, on every well-constituted mind, is and must be the direct contrary. No doubt, the testimony of natural reason, on whatever exercised, must of necessity stop short of those truths which it is the object of revelation to make known; but, while it places the existence and principal attributes of a Deity on such grounds as to render doubt absurd and atheism ridiculous, it unquestionably opposes no natural or necessary obstacle to further progress: on the contrary, by cherishing as a vital principle an unbounded spirit of inquiry, and ardency of expectation, it unfetters the mind from prejudices of every kind, and leaves it open and free to every impression of a higher nature, which it is susceptible of receiving, guarding only against enthusiasm and self-deception by a habit of strict investigation, but encouraging, rather than suppressing, every thing that can offer a prospect or a hope beyond the present obscure and unsatisfactory state. The character of the true philosopher is to hope all things not impossible, and to believe all things not unreasonable. He who has seen obscurities which appeared impenetrable, in physical and mathematical science, suddenly dispelled, and the most barren and unpromising fields of inquiry converted, as if by inspiration, into rich and inexhaustible springs of knowledge and power, on a simple change of our point of view, or by merely bringing to bear on them some principle which it never occurred before to try, will surely be the very last to acquiesce in any dispiriting prospects of either the present or future destinies of mankind; while, on the other hand, the boundless views of intellectual and moral, as well as material relations, which open on him on all hands, in the course of these pursuits, the knowledge of the trivial place he occupies in the scale of creation, and the sense, continually pressed

upon him, of his own weakness and incapacity to suspend or modify the slightest movement of the vast machinery he sees in action around him, must effectually convince him that humility of pretension, no less than confidence of hope, is what best becomes his character.

(6.) But while we thus vindicate the study of natural philosophy from a charge at one time formidable from the pertinacity and acrimony with which it was urged, and still occasionally brought forward to the distress and disgust of every well constituted mind, we must take care that the testimony afforded by science to religion, be its extent or value what it may, shall be at least independent, unbiassed, and spontaneous. We do not here allude to such reasoners as would make all nature bend to their narrow interpretations of obscure and difficult passages in the sacred writings: such a course might well become the persecutors of Galileo and the other bigots of the fifteenth and sixteenth centuries, but can only be adopted by dreamers in the present age. But, without going these lengths, it is no uncommon thing to find persons earnestly attached to science, and anxious for its promotion, who yet manifest a morbid sensibility on points of this kind,—who exult and applaud when any fact starts up explanatory (as they suppose) of some scriptural allusion, and who feel pained and disappointed when the general course of discovery in any department of science runs wide of the notions with which particular passages in the Bible may have impressed themselves. To persons of such a frame of mind it ought to suffice to remark, on the one hand, that truth can never be opposed to truth, and, on the other, that error is only to be effectually confounded by searching deep and tracing it to its source. Nevertheless, it were much to be wished that such persons, estimable and excellent as they for the most part are, before they throw the weight of their applause or discredit into the scale of scientific opinion on such grounds, would reflect, first, that the credit and respectability of *any* evidence may be destroyed by tampering with its *honesty*; and, secondly, that this very disposition of mind implies a lurking mistrust in its own principles, since the

grand, and, indeed, only character of truth, is its capability of enduring the test of universal experience, and coming unchanged out of every possible form of *fair* discussion.

(7.) But if science may be vilified by representing it as opposed to religion, or trammelled by mistaken notions of the danger of free inquiry, there is yet another mode by which it may be degraded from its native dignity; and that is, by placing it in the light of a mere appendage to, and caterer for, our pampered appetites. The question "*cui bono*," to what practical end and advantage do your researches tend? is one which the speculative philosopher, who loves knowledge for its own sake, and enjoys, as a rational being should enjoy, the mere contemplation of harmonious and mutually dependent truths, can seldom hear without a sense of humiliation. He feels that there is a lofty and disinterested pleasure in his speculations, which ought to exempt them from such questioning. Communicating, as they do, to his own mind the purest happiness (after the exercise of the benevolent and moral feelings) of which human nature is susceptible, and tending to the injury of no one, he might surely allege *this* as a sufficient and direct reply to those who, having themselves little capacity, and less relish, for intellectual pursuits, are constantly repeating upon him this inquiry. But if he can bring himself to descend from this high but fair ground, and justify himself, his pursuits, and his pleasures, in the eyes of those around him, he has only to point to the history of all science, where speculations apparently the most unprofitable have almost invariably been those from which the greatest practical applications have emanated. What, for instance, could be apparently more unprofitable than the dry speculations of the ancient geometers on the properties of the conic sections, or than the dreams of Kepler (as they would naturally appear to his contemporaries) about the numerical harmonies of the universe? Yet these are the steps by which we have risen to a knowledge of the elliptic motions of the planets, and the law of gravitation, with all its splendid theoretical consequences, and its inestimable practical results. The ridicule attached to

"*Swing-swangs*," in Hooke's* time, did not prevent him from reviving the proposal of the *pendulum* as a standard of measure, since so admirably wrought into practice by the genius and perseverance of captain Kater;—nor did that which Boyle encountered, in his researches on the elasticity and pressure of the air, act as any obstacle to the train of discovery which terminated in the steam-engine. The dreams of the alchemists led them on in the path of experiment, and drew attention to the wonders of chemistry, while they brought their advocates (it must be admitted) to merited contempt and ruin. But in this case, it was moral dereliction which gave to ridicule a weight and power not necessarily or naturally belonging to it: but among the alchemists were men of superior minds, who reasoned while they worked, and who, not content to grope always in the dark, and blunder on their object, sought carefully, in the observed nature of their agents, for guides in their pursuits;—to these we owe the creation of experimental philosophy.

(8.) Not that it is meant, by any thing above said, to assert, that there is no such thing as a great or a little in speculative philosophy, or to place the solution of an enigma on a level with the developement of a law of nature; still less to adopt the homely definition of Smith,† that a philosopher is a person whose trade it is to do nothing, and speculate on every thing. The speculations of the natural philosopher, however remote they may, for a time, lead him from beaten tracks and every-day uses, being grounded in the realities of nature, have all, of necessity, a practical application: nay, more, such applications form the very criterions of their truth; they afford the readiest and completest verifications of his theories,—verifications which he will no more neglect to test them by, than an arithmetician would omit to *prove* his sums, or a cautious geometer to try his general theorems, by particular cases.‡

* Hooke's Posthumous Works. Lond. 1705—p. 472, and p. 458.
† Wealth of Nations, book i. chap. i. p. 15.
‡ On this subject, we cannot forbear citing a passage from one of the most profound, but, at the same time, popular writers of our time, on a

(9.) After all, however, it must be confessed, that, to minds unacquainted with science, and unused to consider the mutual dependencies of its various branches, there is something neither unnatural nor altogether blamable in the ready occurrence of this question of direct advantage. It requires some habit of abstraction, some penetration of the mind with a tincture of scientific inquiry, some conviction of the value of those estimable and treasured principles, which lie concealed in the most common and homely facts,—some experience, in fine, of success in developing and placing them in evidence, announcing them in precise terms, and applying them to the explanation of other facts of a less familiar character, or to the accomplishment of some obviously useful purpose,—to cure the mind of this tendency to rush at once upon its object, to undervalue the means in over-estimation of the end, and, while gazing too intently at the goal which alone it has been accustomed to desire, to lose sight of the richness and variety of the prospects that offer themselves on either hand on the road.

(10.) We must never forget that it is principles, not phenomena,—laws, not insulated, independent facts,—which are the objects of inquiry to the natural philosopher. As truth is single, and consistent with itself, a principle may be as completely and as plainly elucidated by the most familiar and simple fact, as by the most imposing and uncommon phenomenon. The colors which glitter on a soap-bubble are the immediate consequence of a principle the most important from the variety of phenomena it explains, and the most beautiful, from its simplicity and compendious

subject unconnected, it is true, with our own, but bearing strongly on the point before us. "But, if science be manifestly incomplete, and yet of the highest importance, it would surely be most unwise to restrain inquiry, conducted on just principles, even where the immediate practical utility of it was not visible. In mathematics, chemistry, and every branch of natural philosophy, how many are the inquiries necessary for their improvement and completion, which, taken separately, do not appear to lead to any specifically advantageous purpose! How many useful inventions, and how much valuable and improving knowledge, would have been lost, if a rational curiosity, and a mere love of information, had not generally been allowed to be a sufficient motive for the search after truth!"—Malthus's Principles of Political Economy, p. 16.

neatness, in the whole science of optics. If the nature of periodical colors can be made intelligible by the contemplation of such a trivial object, from that moment it becomes a noble instrument in the eye of correct judgment; and to blow a large, regular, and durable soap-bubble, may become the serious and praiseworthy endeavor of a sage, while children stand round and scoff, or children of a larger growth hold up their hands in astonishment at such waste of time and trouble. To the natural philosopher there is no natural object unimportant or trifling. From the least of nature's works he may learn the greatest lessons. The fall of an apple to the ground may raise his thoughts to the laws which govern the revolutions of the planets in their orbits; or the situation of a pebble may afford him evidence of the state of the globe he inhabits, myriads of ages ago, before his species became its denizens.

(11.) And this is, in fact, one of the great sources of delight which the study of natural science imparts to its votaries. A mind which has once imbibed a taste for scientific inquiry, and has learnt the habit of applying its principles readily to the cases which occur, has within itself an inexhaustible source of pure and exciting contemplations:—one would think that Shakspeare had such a mind in view, when he describes a contemplative man as finding

> "Tongues in trees—books in the running brooks—
> Sermons in stones—and good in every thing."

Accustomed to trace the operation of general causes, and the exemplification of general laws, in circumstances where the uninformed and uninquiring eye perceives neither novelty nor beauty, he walks in the midst of wonders: every object which falls in his way elucidates some principle, affords some instruction, and impresses him with a sense of harmony and order. Nor is it a mere passive pleasure, which is thus communicated. A thousand questions are continually arising in his mind, a thousand subjects of inquiry presenting themselves, which keep his faculties in constant exercise, and his thoughts perpetually on the wing, so that lassitude is excluded from his life, and that

craving after artificial excitement and dissipation of mind, which leads so many into frivolous, unworthy, and destructive pursuits, is altogether eradicated from his bosom.

(12.) It is not one of the least advantages of these pursuits, which, however, they possess in common with every class of intellectual pleasures, that they are altogether independent of external circumstances, and are to be enjoyed in every situation in which a man can be placed in life. The highest degrees of worldly prosperity are so far from being incompatible with them, that they supply additional advantages for their pursuit, and that sort of fresh and renewed relish which arises partly from the sense of contrast, partly from experience of the peculiar pre-eminence they possess over the pleasures of sense, in their capability of unlimited increase, and continual repetition, without satiety or distaste. They may be enjoyed, too, in the intervals of the most active business; and the calm and dispassionate interest with which they fill the mind renders them a most delightful retreat from the agitations and dissensions of the world, and from the conflict of passions, prejudices, and interests, in which the man of business finds himself continually involved. There is something in the contemplation of general laws which powerfully persuades us to merge individual feeling, and to commit ourselves unreservedly to their disposal; while the observation of the calm, energetic regularity of nature, the immense scale of her operations, and the certainty with which her ends are attained, tends, irresistibly, to tranquillize and reassure the mind, and render it less accessible to repining, selfish, and turbulent emotions. And this it does not by debasing our nature into weak compliances and abject submission to circumstances, but by filling us, as from an inward spring, with a sense of nobleness and power, which enables us to rise superior to them, by showing us our strength, and innate dignity, and by calling upon us for the exercise of those powers and faculties by which we are susceptible of the comprehension of so much greatness, and which form, as it were, a link between ourselves and the best and noblest benefactors of our species, with whom we hold com-

munion in thoughts, and participate in discoveries, which have raised them above their fellow-mortals, and brought them nearer to their Creator.

CHAP. II.

OF ABSTRACT SCIENCE AS A PREPARATION FOR THE STUDY OF PHYSICS.—A PROFOUND ACQUAINTANCE WITH IT NOT INDISPENSABLE FOR A CLEAR UNDERSTANDING OF PHYSICAL LAWS.—HOW A CONVICTION OF THEIR TRUTH MAY BE OBTAINED WITHOUT IT.—INSTANCES.—FURTHER DIVISION OF THE SUBJECT.

(13.) Science is the knowledge of many, orderly and methodically digested and arranged, so as to become attainable by one. The knowledge of reasons and their conclusions constitutes *abstract*, that of causes and their effects, and of the laws of nature, *natural science*.

(14.) Abstract science is independent of a system of nature,—of a creation,—of every thing, in short, except memory, thought, and reason. Its objects are, first, those primary existences and relations which we cannot even conceive not to *be*, such as space, time, number, order, &c.; and, secondly, those artificial forms, or symbols, which thought has the power of creating for itself at pleasure, and substituting as representatives, by the aid of memory, for combinations of those primary objects and of its own conceptions,—either to facilitate the act of reasoning respecting them, or as convenient deposits of its own conclusions, or for their communication to others. Such are, first, *language*, oral or written; its conventional forms, which constitute grammar, and the rules for its use in argument, in which consists the logic of the schools; secondly, *notation*, which, applied to *number*, is *arithmetic*,—and, to the more general relations of abstract quantity or order, is *algebra*;

and, thirdly, that higher kind of logic, which teaches us to use our reason in the most advantageous manner for the discovery of truth; which points out the criterions by which we may be sure we have attained it; and which, by detecting the sources of error, and exposing the haunts where fallacies are apt to lurk, at once warns us of their danger, and shows us how to avoid them. This greater logic may be termed *rational;** while, to that inferior department which is conversant with words alone, the epithet *verbal*† may, for distinction, be applied.

(15.) A certain moderate degree of acquaintance with abstract science is highly desirable to one who would make any considerable progress in physics. As the universe exists in time and place; and as motion, velocity, quantity, number, and order, are main elements of our knowledge of external things and their changes, an acquaintance with these, abstractedly considered, (that is to say, independent of any consideration of the particular things moved, measured, counted, or arranged,) must evidently be a useful preparation for the more complex study of nature. But there is yet another recommendation of such sciences as a preparation for the study of natural philosophy. Their objects are so definite, and our notions of them so distinct, that we can reason about them with an assurance, that the words and signs used in our reasonings are full and true representatives of the things signified; and, consequently, that when we use language or signs in argument, we neither, by their use, introduce extraneous notions, nor exclude any part of the case before us from consideration. For example: the words space, square, circle, a hundred, &c., convey to the mind notions so complete in themselves, and so distinct from every thing else, that we are sure, when we use them, we know and have in view the whole of our own meaning. It is widely different with words expressing natural objects and mixed relations. Take, for instance, *iron*. Different persons attach very different ideas to this word. One who has never heard of magnetism has

* Λογὸς, *ratio*, reason. † Λογος, *verbum*, a word.

a widely different notion of *iron*, from one in the contrary predicament. The vulgar, who regard this metal as incombustible, and the chemist, who sees it burn with the utmost fury, and who has other reasons for regarding it as one of the most combustible bodies in nature;—the poet, who uses it as an emblem of rigidity; and the smith and engineer, in whose hands it is plastic, and moulded like wax into every form;—the jailer, who prizes it as an obstruction, and the electrician, who sees in it only a channel of open communication by which that most impassable of obstacles, the air, may be traversed by his imprisoned fluid, have all different and all imperfect notions of the same word. The meaning of such a term is like a rainbow—every body sees a different one, and all maintain it to be the same. So it is with nearly all our terms of sense. Some are indefinite, as hard or soft, light or heavy (terms which were at one time the sources of innumerable mistakes and controversies;) some excessively complex, as man, life, instinct. But, what is worst of all, some, nay most, have two or three meanings, sufficiently distinct from each other to make a proposition true in one sense and false in another, or even false altogether, yet not distinct enough to keep us from confounding them in the process by which we arrived at it, or to enable us immediately to recognise the fallacy when led to it by a train of reasoning, each step of which we *think* we have examined and approved. Surely those who thus attach two senses to one word, or superadd a new meaning to an old one, act as absurdly as colonists who distribute themselves over the world, naming every place they come to by the names of those they have left, till all distinctions of geographical nomenclature are confounded, and till we are unable to decide whether an occurrence stated to have happened at Windsor took place in Europe, America, or Australia.*

* It were much to be wished that navigators would be more cautious in laying themselves open to a similar censure. On looking hastily over a map of the world, we see three Melville Islands, two King George's Sounds, and Cape Blancos innumerable.

(16.) It is, in fact, in this double or incomplete sense of words that we must look for the origin of a very large portion of the errors into which we fall. Now, the study of the abstract sciences, such as arithmetic, geometry, algebra, &c., while they afford scope for the exercise of reasoning about objects that are, or, at least, may be conceived to be, external to us, yet, being free from these sources of error and mistake, accustom us to the strict use of language as an instrument of reason, and by familiarizing us, in our progress towards truth, to walk uprightly and straight-forward on firm ground, give us that proper and dignified carriage which could never be acquired by having always to pick our steps among obstructions and loose fragments, or to steady them in the reeling tempest of conflicting meanings.

(17.) But there is yet another point of view under which some acquaintance with abstract science may be regarded as highly desirable in general education, if not indispensably necessary, to impress on us the distinction between strict and vague reasoning, to show us what demonstration really *is*, and to give us thereby a full and intimate sense of the nature and strength of the evidence on which our knowledge of the actual system of nature, and the laws of natural phenomena, rests. For this purpose, however, a very moderate acquaintance with the more elementary branches of mathematics may suffice. The chain is laid before us, and every link is submitted to our unreserved examination, if we have patience and inclination to enter on such detail. Hundreds have gone through it, and will continue to do so; but, for the generality of mankind, it is enough to satisfy themselves of the solidity and adamantine texture of its materials, and the unreserved exposure of its weakest, as well as its strongest parts. If, however, we content ourselves with this general view of the matter, we must be content also to take on trust, that is, on the authority of those who have examined deeper, every conclusion which cannot be made apparent to our senses. Now among these there are many so very surprising, indeed apparently so extravagant, that it is quite impossible for any inquiring mind to rest contented with a mere hearsay

statement of them,—we feel irresistibly impelled to inquire further into their truth. What mere assertion will make any man believe, that in one second of time, in one beat of the pendulum of a clock, a ray of light travels over 192,000 miles, and would therefore perform the tour of the world in about the same time that it requires to wink with our eyelids, and in much less than a swift runner occupies in taking a single stride? What mortal can be made to believe, without demonstration, that the sun is almost a million times larger than the earth? and that, although so remote from us, that a cannon ball shot directly towards it, and maintaining its full speed, would be twenty years in reaching it, it yet affects the earth by its attraction in an inappreciable instant of time?—a closeness of union of which we can form but a feeble, and totally inadequate, idea, by comparing it to any material connection; since the communication of an impulse to such a distance, by any solid intermedium we are acquainted with, would require, not moments, but whole years. And when, with pain and difficulty, we have strained our imagination to conceive a distance so vast, a force so intense and penetrating, if we are told that the one dwindles to an insensible point, and the other is unfelt at the nearest of the fixed stars, from the mere effect of their remoteness, while among those very stars are some whose actual splendor exceeds by many hundred times that of the sun itself, although we may not deny the truth of the assertion, we cannot but feel the keenest curiosity to know *how* such things were ever made out.

(18.) The foregoing are among those results of scientific research which, by their magnitude, seem to transcend our powers of conception. There are others, again, which, from their minuteness, would appear to elude the grasp of thought, much more of distinct and accurate measurement. Who would not ask for demonstration, when told that a gnat's wing, in its ordinary flight, beats many hundred times in a second? or that there exist animated and regularly organized beings, many thousands of whose bodies, laid close together, would not extend an inch? But what are these

to the astonishing truths which modern optical inquiries have disclosed, which teach us that every point of a medium through which a ray of light passes is affected with a succession of periodical movements, regularly recurring at equal intervals, no less than five hundred millions of millions of times in a single second! that it is by such movements, communicated to the nerves of our eyes, that we see—nay more, that it is the *difference* in the frequency of their recurrence which affects us with the sense of the diversity of color; that, for instance, in acquiring the sensation of redness, our eyes are affected four hundred and eighty-two millions of millions of times; of yellowness, five hundred and forty-two millions of millions of times; and of violet, seven hundred and seven millions of millions of times per second.* Do not such things sound more like the ravings of madmen, than the sober conclusions of people in their waking senses?

(19.) They are, nevertheless, conclusions to which any one may most certainly arrive, who will only be at the trouble of examining the chain of reasoning by which they have been obtained; but, in order to do this, something beyond the mere elements of abstract science is required. Waving, however, such instances as these, which, after all, are rather calculated to surprise and astound than for any other purpose, it must be observed that it is not possible to satisfy ourselves completely that we *have* arrived at a true statement of any law of nature, until, setting out from such statement, and making it a foundation of reasoning, we can show, by strict argument, that the facts observed must follow from it as necessary logical consequences, and *this*, not vaguely and generally, but with all possible precision in time, place, weight, and measure.

(20.) To do this, however, as we shall presently see, requires in many cases a degree of knowledge of mathematics and geometry altogether unattainable by the generality of mankind, who have not the leisure, even if they all had

* Young. Lectures on Nat. Phil. ii. 627. See also Phil. Trans. 1801-2.

the capacity, to enter into such inquiries, some of which are indeed of that degree of difficulty that they can be only successfully prosecuted by persons who devote to them their whole attention, and make them the serious business of their lives. But there is scarcely any person of good ordinary understanding, however little exercised in abstract inquiries, who may not be readily made to comprehend at least the general train of reasoning by which any of the great truths of physics are deduced, and the essential bearings and connections of the several parts of natural philosophy. There are whole branches too, and very extensive and important ones, to which mathematical reasoning has never been at all applied; such as chemistry, geology, and natural history in general, and many others, in which it plays a very subordinate part, and of which the essential principles, and the grounds of application to useful purposes, may be perfectly well understood by a student who possesses no more mathematical knowledge than the rules of arithmetic; so that no one need be deterred from the acquisition of knowledge, or even from active original research in such subjects, by a want of mathematical information. Even in those branches which, like astronomy, optics, and dynamics, are almost exclusively under the dominion of mathematics, and in which no effectual progress can be made without *some* acquaintance with geometry, the principal *results* may be perfectly understood without it. To one incapable of following out the intricacies of mathematical demonstration, the conviction afforded by verified predictions must stand in the place of that purer and more satisfactory reliance which a verification of every step in the process of reasoning can alone afford, since every one will acknowledge the validity of pretensions which he is in the daily habit of seeing brought to the test of practice.

(21.) Among the verifications of this practical kind which abound in every department of physics, there are none more imposing than the precise prediction of the greater phenomena of astronomy; none, certainly, which carry a broader conviction home to every mind from their notoriety and unequivocal character. The prediction of

eclipses has, accordingly, from the earliest ages, excited the admiration of mankind, and been one grand instrument by which their allegiance (so to speak) to natural science, and their respect for its professors, has been maintained; and though strangely abused in unenlightened ages by the supernatural pretensions of astrologers, the credence given even to their absurdities, shows the force of this kind of evidence on men's minds. The predictions of astronomers are, however, now far too familiar to endanger the just equipoise of our judgment, since even the return of comets, true to their paths and exact to the hour of their appointment, has ceased to amaze, though it must ever delight all who have souls capable of being penetrated by such beautiful instances of accordance between theory and facts. But the age of mere wonder in such things is past, and men prefer being guided and enlightened to being astonished and dazzled. Eclipses, comets, and the like, afford but rare and transient displays of the powers of calculation, and of the certainty of the principles on which it is grounded. A page of "lunar distances" from the Nautical Almanack is worth all the eclipses that have ever happened for inspiring this necessary confidence in the conclusions of science. That a man, by merely measuring the moon's apparent distance from a star with a little portable instrument held in his hand, and applied to his eye, even with so unstable a footing as the deck of a ship, shall say positively, within five miles, where he is, on a boundless ocean, cannot but appear to persons ignorant of physical astronomy an approach to the miraculous. Yet the alternatives of life and death, wealth and ruin, are daily and hourly staked with perfect confidence on these marvellous computations, which might almost seem to have been devised on purpose to show how closely the extremes of speculative refinement and practical utility can be brought to approximate. We have before us an anecdote communicated to us by a naval officer,* distinguished for the extent and variety of his attainments, which shows how impressive such results may become in practice. He sailed

* Captain Basil Hall, R. N.

from San Blas on the west coast of Mexico, and after a voyage of 8000 miles, occupying 89 days, arrived off Rio de Janeiro, having, in this interval, passed through the Pacific Ocean, rounded Cape Horn, and crossed the South Atlantic, without making any land, or even seeing a single sail, with the exception of an American whaler off Cape Horn. Arrived within a week's sail of Rio, he set seriously about determining, by lunar observations, the precise line of the ship's course and its situation in it at a determinate moment, and having ascertained this within from five to ten miles, ran the rest of the way by those more ready and compendious methods, known to navigators, which can be safely employed for short trips between one known point and another, but which cannot be trusted in long voyages, where the moon is the only sure guide. The rest of the tale we are enabled by his kindness to state in his own words :—"We steered towards Rio de Janeiro for some days after taking the lunars above described, and, having arrived within fifteen or twenty miles of the coast, I hove to at four in the morning till the day should break, and then bore up; for although it was very hazy, we could see before us a couple of miles or so. About eight o'clock, it became so foggy that I did not like to stand in farther, and was just bringing the ship to the wind again before sending the people to breakfast, when it suddenly cleared off, and I had the satisfaction of seeing the great Sugar Loaf Rock, which stands on one side of the harbor's mouth, so nearly right ahead that we had not to alter our course above a point in order to hit the entrance of Rio. This was the first land we had seen for three months, after crossing so many seas, and being set backwards and forwards by innumerable currents and foul winds." The effect on all on board might well be conceived to have been electric; and it is needless to remark how essentially the authority of a commanding officer over his crew may be strengthened by the occurrence of such incidents, indicative of a degree of knowledge and consequent power beyond their reach.

(22.) But even such results as these, striking as they are, yet fall short of the force with which conviction is urged

upon us, when, through the medium of reasoning too abstract for common apprehension, we arrive at conclusions which outrun experience, and describe beforehand what will happen under new combinations, or even correct imperfect experiments, and lead us to a knowledge of facts contrary to received analogies drawn from an experience wrongly interpreted or over-hastily generalized. To give an example:—every body knows that objects viewed through a transparent medium, such as water or glass, appear distorted or displaced. Thus a stick in water appears bent, and an object seen through a prism or wedge of glass seems to be thrown aside from its true place. This effect is owing to what is called the *refraction* of light; and a simple rule discovered by Willebrod Snell enables any one to say exactly *how much* the stick will be bent, and *how far*, and in what *direction*, the apparent situation of an object seen through the glass will deviate from the real one. If a shilling be laid at the bottom of a basin of water, and viewed obliquely, it will appear to be raised by the water; if, instead of water, spirits of wine be used, it will appear more raised; if oils, still more:—but in none of these cases will it appear to be thrown *aside* to the *right* or *left* of its true place, however the eye be situated. The *plane*, in which are contained the eye, the object, and the point in the surface of the liquid at which the object is seen, is an upright or *vertical* plane; and this is one of the principal characters in the *ordinary refraction* of light, viz. that the ray by which we see an object through a refracting surface, although it undergoes a bending, and is, as it were, broken at the surface, yet, in pursuing its course to the eye, does not *quit a plane perpendicular to the refracting surface*. But there are again other substances, such as rock-crystal, and especially Iceland spar, which possess the singular property of *doubling* the image or appearance of an object seen through them in certain directions; so that, instead of seeing one object, we see two, side by side, when such a crystal or spar is interposed between the object and the eye; and if a ray, or small sunbeam, be thrown upon a surface of either of these substances, it will be split into two, making an angle with each other, and each pursuing its own separate course,—

this is called *double refraction*. Now of these images or doubly refracted rays, *one* always follows the same rule as if the substance were glass or water: its deviation can be correctly calculated by Snell's law above mentioned, and it does not quit the plane perpendicular to the refracting surface. The other ray, on the contrary, (which is therefore said to have undergone *extraordinary refraction*,) *does* quit that plane, and the amount of its deviation from its former course requires for its determination a much more complicated rule, which cannot be understood, or even stated, without a pretty intimate knowledge of geometry. Now, rock-crystal and Iceland spar differ from glass in a very remarkable circumstance. They affect naturally certain regular figures, not being found in shapeless lumps, but in determinate geometrical forms; and they are susceptible of being cleft or split much easier in certain directions than in others—they have a *grain* which glass has not. When other substances having this peculiarity (and which are called *crystallized* substances) were examined, they were all, or by far the greater part, found to possess this singular property of *double refraction;* and it was very natural to conclude, therefore, that the same thing took place in all of them, viz. that of the two rays into which any beam of light falling on the surface of such a substance was split, or of the two images of an object seen through it, *one* only was turned aside out of its *plane*, and *extraordinarily* refracted, while the other followed the *ordinary* rule. Accordingly this was supposed to be the case; and not only so, but, from some trial and measurements purposely made by a philosopher of great eminence, it was considered to be a fact sufficiently established by experiment.

(23.) Perhaps we might have remained long under this impression, for the measurements are delicate, and the subject very difficult. But it has lately been demonstrated by an eminent French philosopher and mathematician, M. Fresnel, that, granting certain *principles* or postulates, all the phenomena of double refraction, including, perhaps, the greatest variety of facts that have ever yet been arranged under one general head, may be satisfactorily explained

and deduced from them by strict mathematical calculation; and *that*, when applied to the cases first mentioned, these principles give a satisfactory account of the *want* of the extraordinary image; *that* when applied to such cases as those of rock-crystal or Iceland spar, they also give a correct account of both the images, and agree in their conclusions with the rules before ascertained for them: but so far from coinciding with that part of the previous statement, which would make these conclusions extend to all crystallized substances, M. Fresnel's principles lead to a conclusion quite opposite, and point to a *fact* which had never been observed, viz. that in by far the greater number of crystallized substances which possess the property of double refraction, *neither* of the images follows the ordinary law, but both undergo a deviation from their original plane. Now this had never been observed to be the case in any previous trial, and all opinion was against it. But when put to the test of experiment in a great variety of new and ingenious methods, it was found to be fully verified: and to complete the evidence, the substances on whose imperfect examination the first erroneous conclusion was founded, having been lately subjected to a fresh and more scrupulous examination, the result has shown the insufficiency of the former measurements, and proved in perfect accordance with the newly discovered laws. Now it will be observed in this case, first, that, so far from the principles assumed by M. Fresnel being at all obvious, they are extremely remote from ordinary observation; and, secondly, that the chain of reasoning by which they are brought to the test, is one of such length and complexity, and the purely mathematical difficulty of their application so great, that no *mere* good common sense, no general tact or ordinary practical reasoning, would afford the slightest chance of threading their mazes. Cases like this are the triumph of theories. They show at once how large a part pure reason has to perform in our examination of nature, and how implicit our reliance ought to be on that powerful and methodical system of rules and processes which constitute the modern mathematical analysis, in all the more difficult applications of exact calculation to her phenomena.

(24.) To take an instance more within ordinary apprehension. An eminent living geometer had proved by calculations, founded on strict optical principles, that in the *centre of the shadow* of a small circular plate of metal, exposed in a dark room to a beam of light emanating from a *very small brilliant point*, there ought to be no darkness,—in fact, *no shadow* at that place; but, on the contrary, a degree of illumination precisely as bright as if the metal plate were away. Strange and even impossible as this conclusion may seem, it has been put to the trial, and found perfectly correct.

(25.) We shall now proceed to consider more particularly, and in detail,—

I. The nature and objects immediate and collateral of physical science, as regarded in itself, and in its application to the practical purposes of life, and its influence on the well-being and progress of society.
II. The principles on which it relies for its successful prosecution, and the rules by which a systematic examination of nature should be conducted, with examples illustrative of their influence.
III. The subdivision of physical science into distinct branches, and their mutual relations.

CHAP. III.

OF THE NATURE AND OBJECTS, IMMEDIATE AND COLLATERAL, OF PHYSICAL SCIENCE, AS REGARDED IN ITSELF, AND IN ITS APPLICATION TO THE PRACTICAL PURPOSES OF LIFE, AND ITS INFLUENCE ON THE WELL-BEING AND PROGRESS OF SOCIETY.

(26.) The first thing impressed on us from our earliest infancy is, that events do not succeed one another at ran-

dom, but with a certain degree of order, regularity, and connection;—some constantly, and, as we are apt to think, immutably,—as the alternation of day and night, summer and winter,—others contingently, as the motion of a body from its place if pushed, or the burning of a stick if thrust into the fire. The knowledge that the former class of events *has* gone on, uninterruptedly, for ages beyond all memory, impresses us with a strong expectation that it will continue to do so in the same manner; and thus our notion of an *order of nature* is originated and confirmed. If every thing were equally regular and periodical, and the succession of events liable to no change depending on our own will, it may be doubted whether we should ever think of looking for causes. No one regards the night as the cause of the day, or the day of night. They are alternate effects of a common cause, which their regular succession alone gives us no sufficient clew for determining. It is chiefly, perhaps entirely, from the other or contingent class of events that we gain our notions of cause and effect. From them alone we gather that there are such things as laws of nature. The very idea of a law includes that of contingency. "*Si quis mala carmina condidisset, fuste ferito;*" if such a case arise, such a course shall be followed,—if the match be applied to the gunpowder, it will explode. Every law is a provision for cases which *may* occur, and has relation to an infinite number of cases that never have occurred, and never will. Now, it is this provision, *à priori*, for contingencies, this contemplation of possible occurrences, and predisposal of what shall happen, that impresses us with the notion of a *law* and a *cause.* Among all the possible combinations of the fifty or sixty elements which chemistry shows to exist on the earth, it is likely, nay almost certain, that *some* have never been formed; that some elements, in some proportions, and under some circumstances, have never yet been placed in relation with one another. Yet no chemist can doubt that it is *already fixed* what they will do when the case does occur. They will obey certain laws, of which we know nothing at present, but which must *be* already fixed, or they could

not be laws. It is not by habit, or by trial and failure, that they will learn what to do. When the contingency occurs, there will be no hesitation, no consultation;—their course will at once be decided, and will always be the same if it occur ever so often in succession, or in ever so many places at one and the same instant. This is the perfection of a law, that it includes all possible contingencies, and ensures implicit obedience,—and of this kind are the laws of nature.

(27.) This use of the word *law*, however, our readers will of course perceive, has relation to us as understanding, rather than to the materials of which the universe consists as obeying, certain rules. To *obey* a law, to act in *compliance* with a rule, supposes an understanding and a will, a power of complying or not, in the being who obeys and complies, which we do not admit as belonging to mere matter. The Divine Author of the universe cannot be supposed to have laid down particular laws, enumerating all individual contingencies, which his materials have understood and obey,—this would be to attribute to him the imperfections of human legislation;—but rather, by creating them, endued with certain fixed qualities and powers, he has impressed them in their origin with the *spirit*, not the *letter*, of his law, and made all their subsequent combinations and relations inevitable consequences of this first impression, by which, however, we would no way be understood to deny the constant exercise of his direct power in maintaining the system of nature, or the ultimate emanation of every energy which material agents exert from his immediate will, acting in conformity with his own laws.

(28.) The discoveries of modern chemistry have gone far to establish the truth of an opinion entertained by some of the ancients, that the universe consists of distinct, separate, indivisible *atoms*, or individual beings so minute as to escape our senses, except when united by millions, and by this aggregation making up bodies of even the smallest visible bulk; and we have the strongest evidence that, although there exist great and essential differences in individuals among these atoms, they may yet all be arranged in a

very limited number of groups or classes, all the individuals of each of which are, to all intents and purposes, *exactly alike* in all their properties. Now, when we see a great number of things precisely alike, we do not believe this similarity to have originated except from a common principle independent of them; and that we recognise this likeness, chiefly by the identity of their deportment under similar circumstances, strengthens rather than weakens the conclusion. A line of spinning-jennies,* or a regiment of soldiers dressed exactly alike, and going through precisely the same evolutions, gives us no idea of independent existence: we must see them act out of concert before we can believe them to have independent wills and properties, not impressed on them from without. And this conclusion, which would be strong even were there only two individuals precisely alike in *all* respects and *for ever*, acquires irresistible force when their number is multiplied beyond the power of imagination to conceive. If we mistake not, then, the discoveries alluded to effectually destroy the idea of an *eternal self-existent matter*, by giving to each of its atoms the essential characters, at once, of a *manufactured article*, and a *subordinate agent*.

(29.) But to ascend to the origin of things, and speculate on the creation, is not the business of the natural philosopher. An humbler field is sufficient for him in the endeavor to discover, as far as our faculties will permit, what *are* these primary qualities originally and unalterably impressed on matter, and to discover the *spirit* of the laws of nature, which includes groups and classes of relations and acts from the *letter* which, as before observed, is presented to us by single phenomena: or if, after all, this should prove impossible; if such a step be beyond our faculties; and the essential qualities of material agents be really *occult*, or incapable of being expressed in any form intelligible to our understandings, at least to approach as near to their comprehension as the nature of the case will allow; and devise such forms of words as shall include and

* Little reels used in cotton mills to twist the thread.

represent the greatest possible multitude and variety of phenomena.

(30.) Now, in this research, there would seem one great question to be disposed of before our inquiries can even be commenced with any thing like a prospect of success, which is, whether the laws of nature themselves *have* that degree of permanence and fixity which can render them subjects of systematic discussion; or whether, on the other hand, the qualities of natural agents are subject to mutation from the lapse of time. To the ancients, who lived in the infancy of the world, or, rather, in the infancy of man's experience, this was a very rational subject of question, and hence their distinctions between corruptible and incorruptible matter. Thus, according to some among them, the matter only of the celestial spaces is pure, immutable, and incorruptible, while all sublunary things are in a constant state of lapse and change; the world becoming paralysed and effete with age, and man himself deteriorating in character, and diminishing at once in intellectual and bodily stature. But to us, who have the experience of some additional thousands of years, the question of permanence is already, in a great measure, decided in the affirmative. The refined speculations of modern astronomy, grounding their conclusions on observations made at very remote periods, have proved to demonstration, that one at least of the great powers of nature, the force of gravitation, the main bond and support of the material universe, has undergone no change in intensity from a high antiquity. The stature of mankind is just what it was three thousand years ago, as the specimens of mummies which have been examined at various times sufficiently show. The intellect of Newton, Laplace or La Grange, may stand in fair competition with that of Archimedes, Aristotle, or Plato; and the virtues and patriotism of Washington with the brightest examples of ancient history.

(31.) Again, the researches of chemists have shown that what the vulgar call corruption, destruction, &c., is nothing but a change of arrangement of the same ingredient elements, the disposition of the same materials into other forms, without the loss or actual destruction of a single atom; and

thus any doubts of the permanence of natural laws are discountenanced, and the whole weight of *appearances* thrown into the opposite scale. One of the most obvious cases of apparent destruction is, when any thing is ground to dust and scattered to the winds. But it is one thing to grind a fabric to powder, and another to annihilate its materials: scattered as they may be, they must fall somewhere, and continue, if only as ingredients of the soil, to perform their humble but useful part in the economy of nature. The destruction produced by fire is more striking: in many cases, as in the burning of a piece of charcoal or a taper, there is no smoke, nothing visibly dissipated and carried away; the burning body wastes and disappears, while nothing *seems* to be produced but warmth and light, which we are not in the habit of considering as substances; and when all has disappeared, except perhaps some trifling ashes, we naturally enough suppose it is gone, lost, destroyed. But when the question is examined more exactly, we detect, in the invisible stream of heated air which ascends from the glowing coal or flaming wax, the *whole* ponderable matter, only united in a new combination with the air, and dissolved in it. Yet, so far from being thereby destroyed, it is only become again what it was before it existed in the form of charcoal or wax, an active agent in the business of the world, and a main support of vegetable and animal life, and is still susceptible of running again and again the same round, as circumstances may determine; so that, for aught we can see to the contrary, the same identical atom may lie concealed for thousands of centuries in a limestone rock; may at length be quarried, set free in the limekiln, mix with the air, be absorbed from it by plants, and, in succession, become a part of the frames of myriads of living beings, till some concurrence of events consigns it once more to a long repose, which, however, no way unfits it from again resuming its former activity.

(32.) Now, this absolute indestructibility of the ultimate materials of the world, in periods commensurate to our experience, and their obstinate retention of the same properties, under whatever variety of circumstances we choose to

place them, however violent and seemingly contradictory to their natures, is, of itself, enough to render it highly improbable that time alone should have any influence over them. All that age or decay can do seems to be included in a wasting of parts which are only dissipated, not destroyed, or in a change of sensible properties, which chemistry demonstrates to arise only from new combinations of the same ingredients. But, after all, the question is one entirely of experience: we cannot be sure, *à priori*, that the laws of nature are *immutable;* but we can ascertain, by inquiry, *whether they change or not;* and to this inquiry all experience answers in the negative. It is not, of course, intended here to deny that great operations, productive of extensive changes in the visible state of nature,—such as, for instance, those contemplated by the geologists, and embracing for their completion vast periods of time,—are constantly going on; but these are consequences and fulfilments of the laws of nature, not contradictions or exceptions to them. No theorist regards such changes as alterations in the fundamental principles of nature; he only endeavors to reconcile them, and show how they result from laws already known, and judges of the correctness of his theory by their ultimate agreement.

(33.) But the laws of nature are not only permanent, but consistent, intelligible, and discoverable with such a moderate degree of research, as is calculated rather to stimulate than to weary curiosity. If we were set down as creatures of another world, in any existing society of mankind, and began to speculate on their actions, we should find it difficult at first to ascertain whether they were subject to any laws at all: but when, by degrees, we had found out that they did consider themselves to be so, and would then proceed to ascertain, from their conduct and its consequences, what these laws were, and in what spirit conceived, though we might not perhaps have much difficulty in discovering single rules applicable to particular cases, yet, the moment we came to generalize, and endeavor from these to ascend, step by step, and discover any steady pervading principle, the mass of incongruities, ab-

surdities, and contradictions, we should encounter, would either dishearten us from further inquiry, or satisfy us that what we were in search of did not exist. It is quite the contrary in nature; there we find no contradictions, no incongruities, but all is harmony. What once is learnt we never have to unlearn. As rules advance in generality, apparent exceptions become regular; and equivoque, in her sublime legislation, is as unheard of as maladministration.

(34.) Living, then, in a world where such laws obtain, and under their immediate dominion, it is manifestly of the utmost importance to know them, were it for no other reason than to be sure, in all we undertake, to have, at least, the law on our side, so as not to struggle in vain against some insuperable difficulty opposed to us by natural causes. What pains and expense would not the alchemists, for instance, have been spared by a knowledge of those simple laws of composition and decomposition, which now preclude all idea of the attainment of their declared object! What an amount of ingenuity, thrown away on the pursuit of the perpetual motion, might have been turned to better use, if the simplest laws of mechanics had been known and attended to by the inventors of innumerable contrivances destined to that end! What tortures, inflicted on patients by imaginary cures of incurable diseases, might have been dispensed with, had a few simple principles of physiology been earlier recognised!

(35.) But if the laws of nature, on the one hand, are invincible opponents, on the other, they are irresistible auxiliaries; and it will not be amiss if we regard them in each of those characters, and consider the great importance of a knowledge of them to mankind,—

I. *In showing us how to avoid attempting impossibilities.*

II. *In securing us from important mistakes in attempting what is, in itself, possible, by means either inadequate, or actually opposed, to the end in view.*

III. *In enabling us to accomplish our ends in the easiest, shortest, most economical, and most effectual manner.*

IV. *In inducing us to attempt, and enabling us to accomplish, objects which, but for such knowledge, we should never have thought of undertaking.*

We shall therefore proceed to illustrate by examples the effect of physical knowledge under each of these heads :—

(36.) Ex. 1. (35.) I. It is not many years since an attempt was made to establish a colliery at Bexhill, in Sussex. The appearance of thin seams and sheets of fossil-wood and wood-coal, with some other indications similar to what occur in the neighborhood of the great coal-beds in the north of England, having led to the sinking of a shaft, and the erection of machinery on a scale of vast expense, not less than eighty thousand pounds are said to have been laid out on this project, which, it is almost needless to add, proved completely abortive, as every geologist would have at once declared it must, the whole assemblage of geological facts being adverse to the existence of a regular coal-bed *in* the Hastings' *sand;* while this, on which Bexhill is situated, is separated from the *coal-strata* by a series of interposed beds of such enormous thickness as to render all idea of penetrating *through* them absurd. The history of mining operations is full of similar cases, where a very moderate acquaintance with the *usual order of nature*, to say nothing of theoretical views, would have saved many a sanguine adventurer from utter ruin.

(37.) Ex. 2. (35.) II. The smelting of iron requires the application of the most violent heat that can be raised, and is commonly performed in tall furnaces, urged by great iron bellows driven by steam-engines. Instead of employing this power to force *air* into the furnace through the intervention of bellows, it was, on one occasion, attempted to employ the steam itself in, apparently, a much less circuitous manner ; viz. by directing the current of steam in a violent blast, from the boiler at once into the fire. From one of the known ingredients of steam being a highly inflammable body, and the other that essential part of the air which supports combustion, it was imagined that this would have the effect of increasing the fire to tenfold fury,

whereas it simply *blew it out;* a result which a slight consideration of the laws of chemical combination, and the state in which the ingredient elements exist in steam, would have enabled any one to predict without a trial.

(38.) Ex. 3. (35.) II. After the invention of the diving-bell, and its success in subaqueous processes, it was considered highly desirable to devise some means of remaining for any length of time under water, and rising at pleasure without assistance, so as either to examine, at leisure, the bottom, or perform, at ease, any work that might be required. Some years ago, an ingenious individual proposed a project by which this end was to be accomplished. It consisted in sinking the hull of a ship made quite water-tight, with the decks and sides strongly supported by shores, and the only entry secured by a stout trap-door, in such a manner, that by disengaging, from within, the weights employed to sink it, it might rise of itself to the surface. To render the trial more satisfactory, and the result more striking, the projector himself made the first essay. It was agreed that he should sink in twenty fathoms water, and rise again without assistance at the expiration of twenty-four hours. Accordingly, making all secure, fastening down his trap-door, and provided with all necessaries, as well as with the means of making signals to indicate his situation, this unhappy victim of his own ingenuity entered and was sunk. No signal was made, and the time appointed elapsed. An immense concourse of people had assembled to witness his rising, but in vain; for the vessel was never seen more. The pressure of the water at so great a depth had, no doubt, been completely under-estimated, and the sides of the vessel being at once crushed in, the unfortunate projector perished before he could even make the signal concerted to indicate his distress.

(39.) Ex. 4. (35.) III. In the granite quarries near Seringapatam the most enormous blocks are separated from the solid rock by the following neat and simple process. The workman having found a portion of the rock sufficiently extensive, and situated near the edge of the part already quarried, lays bare the upper surface, and marks on it a

line in the direction of the intended separation, along which a groove is cut with a chisel about a couple of inches in depth. Above this groove a narrow line of fire is then kindled, and maintained till the rock below is thoroughly heated, immediately on which a line of men and women, each provided with a pot full of cold water, suddenly sweep off the ashes, and pour the water into the heated groove, when the rock at once splits with a clean fracture. Square blocks of six feet in the side, and upwards of eighty feet in length, are sometimes detached by this method, or by another equally simple and efficacious, but not easily explained without entering into particulars of mineralogical detail.*

(40.) Ex. 5. (35.) III. Hardly less simple and efficacious is the process used in some parts of France, where mill-stones are made. When a mass of stone sufficiently large is found, it is cut into a cylinder several feet high, and the question then arises how to subdivide this into horizontal pieces so as to make as many mill-stones. For this purpose horizontal indentations or grooves are chiselled out quite round the cylinder, at distances corresponding to the thickness intended to be given to the mill-stones, into which wedges of dried wood are driven. These are then wetted, or exposed to the night dew, and next morning the different pieces are found separated from each other by the expansion of the wood, consequent on its absorption of moisture; an irresistible natural power thus accomplishing, almost without any trouble, and at no expense, an operation which, from the peculiar hardness and texture of the stone, would otherwise be impracticable but by the most powerful machinery or the most persevering labor.

(41.) Ex. 5. (36.) III. To accomplish our ends quickly is often of, at least, as much importance as to accomplish them with little labor and expense. There are innumerable processes which, if left to themselves, *i. e.* to the ordinary

* Such a block would weigh between four and five hundred thousand pounds. See Dr. Kennedy's "Account of the Erection of a Granite Obelisk of a Single Stone about Seventy Feet high, at Seringapatam."—*Ed. Phil. Trans.* vol. ix. p. 312.

operation of natural causes, are done, and well done, but with extreme slowness; and in such cases it is often of the highest practical importance to accelerate them. The bleaching of linen, for instance, performed in the natural way by exposure to sun, rain, and wind, requires many weeks, or even months, for its completion; whereas, by the simple immersion of the cloth in a liquid, chemically prepared, the same effect is produced in a few hours. The whole circle of the arts, indeed, is nothing but one continued comment upon this head of our subject. The instances above given are selected, not on account of their superior importance, but for the simplicity and *directness* of application of the principles on which they depend, to the objects intended to be attained.

(42.) But so constituted is the mind of man, that his views enlarge, and his desires and wants increase, in the full proportion of the facilities afforded to their gratification, and, indeed, with augmented rapidity, so that no sooner has the successful exercise of his powers accomplished any considerable simplification or improvement of processes subservient to his use or comfort, than his faculties are again on the stretch to extend the limits of his newly acquired power; and having once experienced the advantages which are to be gathered by availing himself of some of the powers of nature to accomplish his ends, he is led thenceforward to regard them all as a treasure placed at his disposal, if he have only the art, the industry, or the good fortune, to penetrate those recesses which conceal them from immediate view. Having once learned to look on knowledge as power, and to avail himself of it as such, he is no longer content to limit his enterprises to the beaten track of former usage, but is constantly led onwards to contemplate objects which, in a previous stage of his progress, he would have regarded as unattainable and visionary, had he even thought of them at all. It is here that the investigation of the hidden powers of nature becomes a mine, every vein of which is pregnant with inexhaustible wealth, and whose ramifications appear to extend in all directions wherever human wants or curiosity may lead us to explore.

(43.) Between the physical sciences and the arts of life there subsists a constant mutual interchange of good offices, and no considerable progress can be made in the one without of necessity giving rise to corresponding steps in the other. On the one hand, every art is in some measure, and many entirely, dependent on those very powers and qualities of the material world which it is the object of physical inquiry to investigate and explain; and, accordingly, abundant examples might be cited of cases where the remarks of experienced artists, or even ordinary workmen, have led to the discovery of natural qualities, elements, or combinations which have proved of the highest importance in physics. Thus (to give an instance), a soap-manufacturer remarks that the residuum of his ley, when exhausted of the alkali for which he employs it, produces a corrosion of his copper boiler, for which he cannot account. He puts it into the hands of a scientific chemist for analysis, and the result is the discovery of one of the most singular and important chemical elements, iodine. The properties of this, being studied, are found to occur most appositely in illustration and support of a variety of new, curious, and instructive views then gaining ground in chemistry, and thus exercise a marked influence over the whole body of that science. Curiosity is excited: the origin of the new substance is traced to the sea-plants from whose ashes the principal ingredient of soap is obtained, and ultimately to the sea-water itself. It is thence hunted through nature, discovered in salt mines and springs, and pursued into all bodies which have a marine origin; among the rest, into sponge. A medical practitioner* then calls to mind a reputed remedy for the cure of one of the most grievous and unsightly disorders to which the human species is subject—the *goître*—which infests the inhabitants of mountainous districts to an extent that in this favored land we have happily no experience of, and which was said to have been originally cured by the ashes of burnt sponge. Led by this indication, he tries the effect of iodine on that complaint, and the result

* Dr. Coindet of Geneva.

establishes the extraordinary fact that this singular substance, taken as a medicine, acts with the utmost promptitude and energy on *goître*, dissipating the largest and most inveterate in a short time, and acting (of course, like all medicines, even the most approved, with occasional failures) as a specific, or natural antagonist, against that odious deformity. It is thus that any accession to our knowledge of nature is sure, sooner or later, to make itself felt in some practical application, and that a benefit conferred on science by the casual observation or shrewd remark of even an unscientific or illiterate person infallibly repays itself with interest, though often in a way that could never have been at first contemplated.

(44.) It is to such observation, reflected upon, however, and matured into a rational and scientific form by a mind deeply imbued with the best principles of sound philosophy, that we owe the practice of vaccination; a practice which has effectually subdued, in every country where it has been introduced, one of the most frightful scourges of the human race, and in some extirpated it altogether. Happily for us, we know only by tradition the ravages of the small-pox, as it existed among us hardly more than a century ago, and as it would in a few years infallibly exist again, were the barriers which this practice, and that of inoculation, oppose to its progress abandoned. Hardly inferior to this terrible scourge on land was, within the last seventy or eighty years, the scurvy at sea. The sufferings and destruction produced by this horrid disorder on board our ships when, as a matter of course, it broke out after a few months' voyage, seem now almost incredible. Deaths to the amount of eight or ten a day in a moderate ship's company; bodies sewn up in hammocks, and washing about the decks for want of strength and spirits on the part of the miserable survivors to cast them overboard; and every form of loathsome and excruciating misery of which the human frame is susceptible:—such are the pictures which the narratives of nautical adventure in those days continually offer.* At present the

* Journal of a Voyage to the South Seas, &c. &c., under the Command of Commodore George Anson in 1740—1744, by Pascoe Thomas,

scurvy is almost completely eradicated in the navy, partly, no doubt, from increased and increasing attention to general cleanliness, comfort, and diet; but mainly from the constant use of a simple and palatable preventive, the acid of the lemon, served out in daily rations. If the gratitude of mankind be allowed on all hands to be the just meed of the philosophic physician, to whose discernment in seizing, and perseverance in forcing it on public notice, we owe the great safeguard of infant life, it ought not to be denied to those whose skill and discrimination have thus strengthened the sinews of our most powerful arm, and obliterated one of the darkest features in the most glorious of all professions.

(45.) These last, however, are instances of simple observation, limited to the point immediately in view, and assuming only so far the character of science as a systematic adoption of good and rejection of evil, when grounded on experience carefully weighed, justly entitle it to do. They are not on that account less appositely cited as instances of the importance of a knowledge of nature and its laws to our well-being; though, like the great inventions of the mariner's compass and of gunpowder, they may have stood, in their origin, unconnected with more general views. They are rather to be looked upon as the spontaneous produce of a territory essentially fertile, than as forming part of the succession of harvests which the same bountiful soil, diligently cultivated, is capable of yielding. The history of iodine above related affords, however, a perfect specimen of the manner in which a knowledge of natural properties and laws, collected from facts having no reference to the object to

Lond. 1745. So tremendous were the ravages of scurvy, that, in the year 1726, admiral Hosier sailed with seven ships of the line to the West Indies, and buried his ships' companies twice, and died himself in consequence of a broken heart. Dr. Johnson, in the year 1778, could describe a sea-life in such terms as these:—"As to the sailor, when you look down from the quarter deck to the space below, you see the utmost extremity of human misery, such crowding, such filth, such stench!"—"A ship is a prison with the chance of being drowned—it is worse—worse in every respect—worse room, worse air, worse food—worse company!" Smollet, who had personal experience of the horrors of a seafaring life in those days, gives a lively picture of them in his Roderick Random.

which they have been subsequently applied, enables us to set in array the resources of nature against herself; and deliberately, of afore-thought, to devise remedies against the dangers and inconveniences which beset us. In this view we might instance, too, the *conductor*, which, in countries where thunder-storms are more frequent and violent than in our own, and at sea (where they are attended with peculiar danger, both from the greater probability of accident, and its more terrible consequences when it does occur,) forms a most real and efficient preservative against the effects of lightning*:—the *safety-lamp*, which enables us to walk with light and security while surrounded with an atmosphere more explosive than gunpowder:—the *life-boat*, which cannot be sunk, and which offers relief in circumstances of all others the most distressing to humanity, and of which a recent invention promises to extend the principle to ships of the largest class:—the *lighthouse*, with the capital improvements which the lenses of Brewster and Fresnel, and the elegant lamp of lieutenant Drummond, have conferred, and promised yet to confer by their wonderful powers, the one of producing the most intense light yet known, the others of conveying it undispersed to great distances:—the discovery of the disinfectant powers of chlorine, and its application to the destruction of miasma and contagion:—that of *quinine*, the essential principle in which reside the febrifuge qualities of the Peruvian bark, a discovery by which posterity is yet to benefit in its full extent, but which has already begun to diffuse *comparative* comfort and health through regions almost desolated by pestiferous exhalations†;—and, if we desist, it is not because the list is ex-

* Throughout France the conductor is recognised as a most valuable and useful instrument; and in those parts of Germany where thunder-storms are still more common and tremendous, they are become nearly universal. In Munich there is hardly a modern house unprovided with them, and of a much better construction than ours—several copper wires twisted into a rope.

† We have been informed by an eminent physician in Rome, (Dr. Morichini,) that a vast quantity of the sulphate of quinine is manufactured there and consumed in the Campagna, with an evident effect in mitigating the severity of the malarious complaints which affect its inhabitants.

hausted, but because a sample, not a catalogue, is intended.

(46.) One instance more, however, we will add, to illustrate the manner in which a most familiar effect, which seemed destined only to amuse children, or, at best, to furnish a philosophic toy, may become a safeguard of human life, and a remedy for a most serious and distressing evil. In needle manufactories the workmen who point the needles are constantly exposed to excessively minute particles of steel which fly from the grindstones, and mix, though imperceptible to the eye, as the finest dust in the air, and are inhaled with their breath. The effect, though imperceptible on a short exposure, yet, being constantly repeated from day to day, produces a constitutional irritation dependent on the tonic properties of the steel, which is sure to terminate in pulmonary consumption; insomuch, that persons employed in this kind of work used scarcely ever to attain the age of forty years.* In vain was it attempted to purify the air before its entry into the lungs by gauzes or linen guards; the dust was too fine and penetrating to be obstructed by such coarse expedients, till some ingenious person bethought him of that wonderful power which every child who searches for its mother's needle with a magnet, or admires the motions and arrangement of a few steel filings on a sheet of paper held above it, sees in exercise. Masks of magnetized steel wire are now constructed and adapted to the faces of the workmen. By these the air is not merely *strained* but *searched* in its passage through them, and each obnoxious atom arrested and removed.

(47.) Perhaps there is no result which places in a stronger light the advantages which are to be derived from a mere knowledge of the *usual order of nature*, without any attempt on our part to modify it, and apart from all consideration of its causes, than the institution of life-assurances. Nothing is more uncertain than the life of a single individual; and it is the sense of this insecurity which has given rise to such institutions. They are, in their nature and objects,

* Dr. Johnson, Memoirs of the Medical Society, vol. v.

the precise reverse of gambling speculations, their object being to equalise vicissitude, and to place the pecuniary relations of numerous masses of mankind, in so far as they extend, on a footing independent of individual casualty. To do this with the greatest possible advantage, or, indeed, with any advantage at all, it is necessary to know the *laws of mortality*, or the average numbers of individuals, out of a great multitude, who die at every period of life from infancy to extreme old age. At first sight this would seem a hopeless inquiry; to some, perhaps, a presumptuous one. But it has been made; and the result is, that, abating extraordinary causes, such as wars, pestilence, and the like, a remarkable regularity *does* obtain, quite sufficient to afford grounds not only for general estimations, but for nice calculations of risk and adventure, such as infallibly to insure the success of any such institution founded on good computations; and thus to confer such stability on the fortunes of families dependent on the exertions of one individual as to constitute an important feature in modern civilization. The only thing to be feared in such institutions is their too great multiplication and consequent competition, by which a spirit of gambling and under-bidding is liable to be generated among their conductors, and the very mischief may be produced, on a scale of frightful extent, which they are especially intended to prevent.

(48.) We have hitherto considered only cases in which a knowledge of natural laws enables us to improve our condition, by counteracting evils of which, but for its possession, we must have remained for ever the helpless victims. Let us now take a similar view of those in which we are enabled to call in nature as an auxiliary to augment our actual power, and capacitate us for undertakings, which without such aid might seem to be hopeless. Now, to this end, it is necessary that we should form a just conception of what those hidden powers of nature *are*, which we can at pleasure call into action;—how far they transcend the measure of human force, and set at naught the efforts, not only of individuals, but of whole nations of men.

(49.) It is well known to modern engineers, that *there is*

virtue in a bushel of coals properly consumed, to raise seventy millions of pounds weight a foot high. This is actually the *average* effect of an engine at this moment working in Cornwall.* Let us pause a moment, and consider what this is equivalent to in matters of practice.

(50.) The ascent of Mont Blanc from the valley of Chamouni is considered, and with justice, as the most toilsome feat that a strong man can execute in two days. The combustion of two pounds of coal would place him on the summit.†

(51.) The Menai Bridge, one of the most stupendous works of art that has been raised by man in modern ages, consists of a mass of iron, not less than four millions of pounds in weight, suspended at a medium height of about 120 feet above the sea. The consumption of seven bushels of coal would suffice to raise it to the place where it hangs.

(52.) The great pyramid of Egypt is composed of granite. It is 700 feet in the side of its base, and 500 in perpendicular height, and stands on eleven acres of ground. Its weight is, therefore, 12,760 millions of pounds, at a medium height of 125 feet; consequently it would be raised by the effort of about 630 chaldrons of coal, a quantity consumed in some founderies in a week.

(53.) The annual consumption of coal in London is estimated at 1,500,000 chaldrons. The effort of this quantity would suffice to raise a cubical block of marble, 2200 feet in the side, through a space equal to its own height, or to pile one such mountain upon another. The Monte Nuovo, near Pozzuoli, (which was erupted in a single night by volcanic fire,) might have been raised by such an effort, from a depth of 40,000 feet, or about eight miles.

(54.) It will be observed, that, in the above statement, the inherent power of fuel is, of necessity, greatly under-

* The engine at Huel Towan. See Mr. Henwood's Statement "of the performance of steam-engines in Cornwall for April, May, and June, 1829." Brewster's Journal, Oct. 1829.—The *highest* monthly average of this engine extends to 79 millions of pounds.

† However, this is not quite a fair statement; a man's daily labor is about 4 lbs. of coals. The extreme toil of this ascent arises from other obvious causes than the mere height.

rated. It is not pretended by engineers that the economy of fuel is yet pushed to its utmost limit, or that the whole effective power is obtained in any application of fire yet devised; so that were we to say 100 millions instead of 70, we should probably be nearer the truth.

(55.) The powers of wind and water, which we are constantly impressing into our service, can scarcely be called latent or hidden; yet it is not fully considered, in general, what they *do* effect for us. Those who would judge of what advantage may be taken of the wind, for example, even on land, (not to speak of navigation,) may turn their eyes on Holland. A great portion of the most valuable and populous tract of this country lies much below the level of the sea, and is only preserved from inundation by the maintenance of embankments. Though these suffice to keep out the abrupt influx of the ocean, they cannot oppose that law of nature, by which fluids, in seeking their level, insinuate themselves through the pores and subterraneous channels of a loose, sandy soil, and keep the country in a constant state of infiltration from below upwards. To counteract this tendency, as well as to get rid of the rain water, which has no natural outlet, pumps worked by windmills are established, in great numbers, on the dams and embankments, which pour out the water, as from a leaky ship, and in effect preserve the country from submersion, by taking advantage of every wind that blows. To drain the Haarlem lake* would seem a hopeless project to any speculators but those who had the steam-engine at their command, or had learnt in Holland what might be accomplished by the constant agency of the desultory but unwearied powers of wind. But the Dutch engineer measures his surface, calculates the number of his pumps, and, trusting to time and his experience of the operation of the winds for the success of his undertaking, boldly forms his plans to lay dry the bed of an

* Its surface is about 40,000 acres, and medium depth about 20 feet. It was proposed to drain it by running embankments across it, and thus cutting it up into more manageable portions to be drained by windmills.

inland sea, of which those who stand on one shore cannot see the other.*

(56.) To gunpowder, as a source of mechanical power, it seems hardly necessary to call attention; yet it is only when we endeavor to *confine* it, that we get a full conception of the immense energy of that astonishing agent. In count Rumford's experiments, twenty-eight grains of powder confined in a cylindrical space, *which it just filled*, tore asunder a piece of iron which would have resisted a strain of 400,000 lbs.†, applied at no greater mechanical disadvantage.

(57.) But chemistry furnishes us with means of calling into sudden action forces of a character infinitely more tremendous than that of gunpowder. The terrific violence of the different fulminating compositions is such, that they can only be compared to those untamable animals, whose ferocious strength has hitherto defied all useful management, or rather to spirits evoked by the spells of a magician, manifesting a destructive and unapproachable power, which makes him but too happy to close his book, and break his wand, as the price of escaping unhurt from the storm he has raised. Such powers are not yet subdued to our purposes, whatever they may hereafter be; but, in the expansive force of gases, liberated slowly and manageably from chemical mixtures, we have a host of inferior, yet still most powerful, energies, capable of being employed in a variety of useful ways, according to emergencies.‡

(58.) Such are the forces which nature lends us for the accomplishment of our purposes, and which it is the province

* No one doubts the *practicability* of the undertaking. Eight or nine thousand chaldrons of coals duly burnt would evacuate the whole contents. But many doubt whether it would be profitable, and some, considering that a few hundreds of fishermen who gain their livelihood on its waters would be dispossessed, deny that it would be *desirable*.

† "Experiments to determine the Force of fired Gunpowder." Phil. Trans. vol. lxxxvii. p. 254. et seq.

‡ See a very ingenious application of this kind in Mr. Babbage's article on Diving, in the Encyc. Metrop.—Others will readily suggest themselves. For instance, the ballast in reserve of a balloon might consist of materials capable of evolving great quantities of hydrogen gas in proportion to their weight, should such be found.

of practical Mechanics to teach us to combine and apply in the most advantageous manner; without which the mere command of power would amount to nothing. Practical Mechanics is, in the most pre-eminent sense, a *scientific art;* and it may be truly asserted, that almost all the great combinations of modern mechanism, and many of its refinements and nicer improvements, are creations of pure intellect, grounding its exertion upon a moderate number of very elementary propositions in theoretical mechanics and geometry. On this head we might dwell long, and find ample matter, both for reflection and wonder; but it would require not volumes merely, but libraries, to enumerate and describe the prodigies of ingenuity which have been lavished on every thing connected with machinery and engineering. By these it is that we are enabled to diffuse over the whole earth the productions of any part of it; to fill every corner of it with miracles of art and labor, in exchange for its peculiar commodities; and to concentrate around us, in our dwellings, apparel and utensils, the skill and workmanship not of a few expert individuals, but of all who, in the present and past generations, have contributed their improvements to the processes of our manufactures.

(59.) The transformations of chemistry, by which we are enabled to convert the most apparently useless materials into important objects in the arts, are opening up to us, every day, sources of wealth and convenience of which former ages had no idea, and which have been pure gifts of science to man. Every department of art has felt their influence, and new instances are continually starting forth of the unlimited resources which this wonderful science developes in the most sterile parts of nature. Not to mention the impulse which its progress has given to a host of other sciences, which will come more particularly under consideration in another part of this discourse; what strange and unexpected results has it not brought to light in its application to some of the most common objects! Who, for instance, would have conceived that linen rags were capable of producing *more than their own weight* of

sugar, by the simple agency of one of the cheapest and most abundant acids?*—that dry bones could be a magazine of nutriment, capable of preservation for years, and ready to yield up their sustenance in the form best adapted to the support of life, on the application of that powerful agent, steam, which enters so largely into all our processes, or of an acid at once cheap and durable?†—that sawdust itself is susceptible of conversion into a substance bearing no remote analogy to bread; and though certainly less palatable than that of flour, yet no way disagreeable, and both wholesome and digestible, as well as highly nutritive?‡ What economy, in all processes where chemical agents are employed, is introduced by the exact knowledge of the proportions in which natural elements unite, and their mutual powers of displacing each other! What perfection in all the arts where fire is employed, either in its more violent applications, (as, for instance, in the smelting of metals by the introduction of well adapted fluxes, whereby we obtain the whole produce of the ore in its purest state,) or in its milder forms, as in sugar refining (the whole modern practice of which depends on a curious and delicate remark of a late eminent scientific chemist on the nice adjustment of temperature at which the crystallization of syrup takes place); and a thousand other arts which it would be tedious to enumerate!

(60.) Armed with such powers and resources, it is no wonder if the enterprise of man should lead him to form and execute projects which, to one uninformed of their grounds, would seem altogether disproportionate. Were they to have been proposed at once, we should, no doubt, have rejected them as such: but developed, as they have been, in the slow succession of ages, they have only taught us that things regarded impossible in one generation may become easy in the next; and that the power of man over

* Bracconot. Annales de Chimie, vol. xii. p. 184.

† D'Arcet. Annales de l'Industrie. Fevrier, 1829.

‡ See Dr. Prout's account of the experiments of professor Autenrieth of Tubingen. Phil. Trans. 1827, p. 381. This discovery, which renders famine next to *impossible*, deserves a higher degree of celebrity than it has obtained.

nature is limited only by the one condition, that it must be exercised in conformity with the laws of nature. He must study those laws as he would the disposition of a horse he would ride, or the character of a nation he would govern; and the moment he presumes either to thwart her fundamental rules, or ventures to measure his strength with hers, he is at once rendered severely sensible of his imbecility, and meets the deserved punishment of his rashness and folly. But if, on the other hand, he will consent to use, without abusing, the resources thus abundantly placed at his disposal, and obey that he may command, there seems scarcely any conceivable limit to the degree in which the *average* physical condition of great masses of mankind may be improved, their wants supplied, and their conveniences and comforts increased. Without adopting such an exaggerated view, as to assert that the meanest inhabitant of a civilized society is superior in physical condition to the lordly savage, whose energy and uncultivated ability gives him a natural predominance over his fellow denizens of the forest,—at least, if we compare like with like, and consider the multitude of human beings who are enabled, in an advanced state of society, to subsist in a degree of comfort and abundance, which at best only a few of the most fortunate in a less civilized state could command, we shall not be at a loss to perceive the principle on which we ought to rest our estimate of the advantages of civilization; and which applies with hardly less force to every degree of it, when contrasted with that next inferior, than to the broad distinction between civilized and barbarous life in general.

(61.) The difference of the degrees in which the individuals of a great community enjoy the good things of life has been a theme of declamation and discontent in all ages; and it is doubtless our paramount duty, in every state of society, to alleviate the pressure of the purely evil part of this distribution as much as possible, and, by all the means we can devise, secure the lower links in the chain of society from dragging in dishonor and wretchedness: but there is a point of view in which the picture is

at least materially altered in its expression. In comparing society, on its present immense scale, with its infant or less developed state, we must at least take care to enlarge every feature in the same proportion. If, on comparing the *very* lowest states in civilized and savage life, we admit a difficulty in deciding to which the preference is due, at least in every superior grade we cannot hesitate a moment; and if we institute a similar comparison in every different stage of its progress, we cannot fail to be struck with the rapid *rate of dilatation* which every degree upward of the scale, so to speak, exhibits, and which, in an estimate of averages, gives an immense preponderance to the present over every former condition of mankind, and, for aught we can see to the contrary, will place succeeding generations in the same degree of superior relation to the present that this holds to those passed away. Or we may put the same proposition in other words, and, admitting the existence of every inferior grade of advantage in a higher state of civilization which subsisted in the preceding, we shall find, first, that, taking state for state, the proportional numbers of those who enjoy the higher degrees of advantage increases with a constantly accelerated rapidity as society advances: and, secondly, that the superior extremity of the scale is constantly enlarging by the addition of new degrees. The condition of a European prince is now as far superior, in the command of real comforts and conveniences, to that of one in the middle ages, as that to the condition of one of his own dependants.

(62.) The advantages conferred by the augmentation of our physical resources through the medium of increased knowledge and improved art have this peculiar and remarkable property,—that they are in their nature diffusive, and cannot be enjoyed in any exclusive manner by a few. An eastern despot may extort the riches and monopolize the art of his subjects for his own personal use; he may spread around him an unnatural splendor and luxury, and stand in strange and preposterous contrast with the general penury and discomfort of his people; he may glitter in jewels of gold and raiment of needle-work; but the wonders of well contrived and executed manufacture which

we use daily, and the comforts which have been invented, tried, and improved upon by thousands, in every form of domestic convenience, and for every ordinary purpose of life, can never be enjoyed by him. To produce a state of things in which the physical advantages of civilized life can exist in a high degree, the stimulus of increasing comforts and constantly elevated desires must have been felt by millions; since it is not in the power of a few individuals to create that wide demand for useful and ingenious applications, which alone can lead to great and rapid improvements, unless backed by that arising from the speedy diffusion of the same advantages among the mass of mankind.

(63.) If this be true of physical advantages, it applies with still greater force to intellectual. Knowledge can neither be adequately cultivated nor adequately enjoyed by a few; and although the conditions of our existence on earth may be such as to preclude an abundant supply of the physical necessities of all who may be born, there is no such law of nature in force against that of our intellectual and moral wants. Knowledge is not, like food, destroyed by use, but rather augmented and perfected. It acquires not, perhaps, a greater certainty, but at least a confirmed authority and a probable duration, by universal assent; and there is no body of knowledge so complete but that it may acquire accession, or so free from error but that it may receive correction in passing through the minds of millions. Those who admire and love knowledge for its own sake ought to wish to see its elements made accessible to all, were it only that they may be the more thoroughly examined into, and more effectually developed in their consequences, and receive that ductility and plastic quality which the pressure of minds of all descriptions, constantly moulding them to their purposes, can alone bestow. But to this end it is necessary that it should be divested, as far as possible, of artificial difficulties, and stripped of all such technicalities as tend to place it in the light of a craft and a mystery, inaccessible without a kind of apprenticeship. Science, of course, like every thing else, has its own

peculiar terms, and, so to speak, its idioms of language; and these it would be unwise, were it even possible, to relinquish: but every thing that tends to clothe it in a strange and repulsive garb, and especially every thing that, to keep up an appearance of superiority in its professors over the rest of mankind, assumes an unnecessary guise of profundity and obscurity, should be sacrificed without mercy. Not to do this, is to deliberately reject the light which the natural unencumbered good sense of mankind is capable of throwing on every subject, even in the elucidation of principles: but where principles are to be applied to practical uses, it becomes absolutely necessary; as all mankind have then an interest in their being so familiarly understood, that no mistakes shall arise in their application.

(64.) The same remark applies to arts. They cannot be perfected till their whole processes are laid open, and their language simplified and rendered universally intelligible. Art is the application of knowledge to a practical end. If the knowledge be merely accumulated experience, the art is *empirical;* but if it be experience reasoned upon and brought under general principles, it assumes a higher character, and becomes a *scientific art*. In the progress of mankind from barbarism to civilized life, the arts necessarily precede science. The wants and cravings of our animal constitution must be satisfied; the comforts, and some of the luxuries, of life must exist. Something must be given to the vanity of show, and more to the pride of power: the round of baser pleasures must have been tried and found insufficient, before intellectual ones can gain a footing; and when they have obtained it, the delights of poetry and its sister arts still take precedence of contemplative enjoyments, and the severer pursuits of thought; and when these in time begin to charm from their novelty, and sciences begin to arise, they will at first be those of pure speculation. The mind delights to escape from the trammels which had bound it to earth, and luxuriates in its newly found powers. Hence the abstractions of geometry—the properties of numbers—the

movements of the celestial spheres—whatever is abstruse, remote, and extramundane—become the first objects of infant science. Applications come late: the arts continue slowly progressive, but their realm remains separated from that of science by a wide gulf which can only be passed by a powerful spring. They form their own language and their own conventions, which none but artists can understand. The whole tendency of empirical art is to bury itself in technicalities, and to place its pride in particular short cuts and mysteries known only to adepts; to surprise and astonish by results, but conceal processes. The character of science is the direct contrary. It delights to lay itself open to inquiry, and is not satisfied with its conclusions, till it can make the road to them broad and beaten: and in its applications it preserves the same character; its whole aim being to strip away all technical mystery, to illuminate every dark recess, and to gain free access to all processes, with a view to improve them on rational principles. It would seem that a union of two qualities almost opposite to each other—a going forth of the thoughts in two directions, and a sudden transfer of ideas from a remote station in one to an equally distant one in the other—is required to start the first idea of *applying science*. Among the Greeks, this point was attained by Archimedes, but attained too late, on the eve of that great eclipse of science which was destined to continue for nearly eighteen centuries, till Galileo in Italy, and Bacon in England, at once dispelled the darkness; the one by his inventions and discoveries, the other by the irresistible force of his arguments and eloquence.

(65.) Finally, the improvement effected in the condition of mankind by advances in physical science as applied to the useful purposes of life, is very far from being limited to their direct consequences in the more abundant supply of our physical wants, and the increase of our comforts. Great as these benefits are, they are yet but steps to others of a still higher kind. The successful results of our experiments and reasonings in natural philosophy, and the incalculable advantages which experience, systematically

consulted and dispassionately reasoned on, has conferred in matters purely physical, tend of necessity to impress something of the well weighed and progressive character of science on the more complicated conduct of our social and moral relations. It is thus that legislation and politics become gradually regarded as experimental sciences; and history, not, as formerly, the mere record of tyrannies and slaughters, which, by immortalizing the execrable actions of one age, perpetuates the ambition of committing them in every succeeding one, but as the archive of experiments, successful and unsuccessful, gradually accumulating towards the solution of the grand problem—how the advantages of government are to be secured with the least possible inconvenience to the governed. The celebrated apophthegm, that nations never profit by experience, becomes yearly more and more untrue. Political economy, at least, is found to have sound principles, founded in the moral and physical nature of man, which, however lost sight of in particular measures—however even temporarily controverted and borne down by clamor—have yet a stronger and stronger testimony borne to them in each succeeding generation, by which they must, sooner or later, prevail. The idea once conceived and verified, that great and noble ends are to be achieved, by which the condition of the whole human species shall be permanently bettered, by bringing into exercise a sufficient quantity of sober thought, and by a proper adaptation of means, is of itself sufficient to set us earnestly on reflecting what ends *are* truly great and noble, either in themselves, or as conducive to others of a still loftier character; because we are not now, as heretofore, hopeless of attaining them. It is not now equally harmless and insignificant, whether we are right or wrong; since we are no longer supinely and helplessly carried down the stream of events, but feel ourselves capable of buffetting at least with its waves, and perhaps of riding triumphantly over them; for why should we despair that the reason which has enabled us to subdue all nature to our purposes, should (if permitted and assisted by the providence of God)

achieve a far more difficult conquest; and ultimately find some means of enabling the collective wisdom of mankind to bear down those obstacles which individual short-sightedness, selfishness, and passion, oppose to all improvements, and by which the highest hopes are continually blighted, and the fairest prospects marred.